BBC

NEAR-DEATH EXPERIENCES *WHAT REALLY HAPPENS*

Science Focus

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THEORY OF EVERYTHING

The ethics of
NAZI RESEARCH DISSECTED

Can our brains
DEAL WITH ECO-ANXIETY?

RACE TO

VENUS

WHAT WE'LL DISCOVER ON EARTH'S TOXIC TWIN

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December 2019

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INSTANT
SAVINGS

SENSATIONAL
SIX

ALL-ROUND CREATIVE GENIUS

tech radar EDITOR'S CHOICE ★★★★★

Digital Camera World ★★★★★

N Photo GOLD AWARD ★★★★★

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Nikon

Are pets bad for the environment? →p95

FROM THE EDITOR

Venus was the first planet humans ever visited. In 1962 the Mariner 2 probe flew past one of our closest neighbours. The spacecraft discovered a hostile world, a place we came to learn was much hotter and more violently toxic than any other planet in our Solar System. A runaway greenhouse gas effect had heated the planet to an average temperature of 462°C, hot enough to melt lead. Venus's punishing environment made return missions unlikely, especially when there was lower hanging fruit in the shape of the Red Planet.

But today, interest in Earth's toxic twin is resurgent. Current tech could support longer missions that get closer to the planet's destructive surface and discover more about its story. For all of the similarities between Earth and Venus – their size and orbits – they're wildly different places. How can something so alien be so close to Earth? Understanding what forged Venus into the planet we see today could tell us which exoplanets might be Earth-like paradises, and which are fiery hellholes. Head to p56 to find out what we'll learn about Venus in the years to come.

Daniel Bennett, Editor

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CONTRIBUTORS

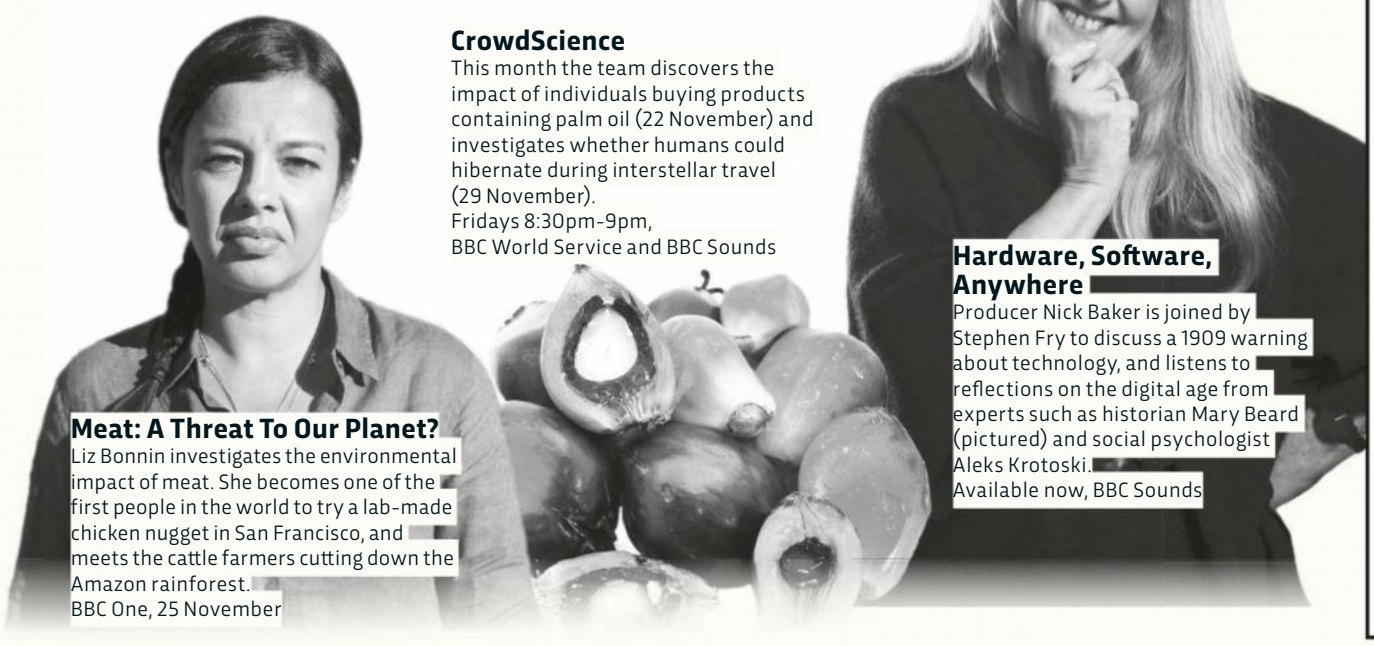
ABIGAIL BEALL
Venus had become something of a forgotten planet, but now space agencies are racing to return. Science writer Abigail finds out why. → p56

CHRISTIAN JARRETT
Could we ever find out what it's like to die? Christian, senior editor for *Psyche*, explores a new field of research which uses hallucinogenic drugs to probe near-death experiences. → p64

FAY DOWKER
Expanding on her PhD supervisor Prof Stephen Hawking's work, physicist Fay is trying to solve the problem of quantum gravity and find a theory of everything. → p74

TOM IRELAND
What happens when a potentially life-saving discovery comes from taboo research? Tom, editor of *The Biologist*, dives into the ethics of immoral science. → p78

ON THE BBC THIS MONTH...



Meat: A Threat To Our Planet?
Liz Bonnin investigates the environmental impact of meat. She becomes one of the first people in the world to try a lab-made chicken nugget in San Francisco, and meets the cattle farmers cutting down the Amazon rainforest.
BBC One, 25 November

CrowdScience
This month the team discovers the impact of individuals buying products containing palm oil (22 November) and investigates whether humans could hibernate during interstellar travel (29 November).
Fridays 8:30pm-9pm,
BBC World Service and BBC Sounds

Hardware, Software, Anywhere
Producer Nick Baker is joined by Stephen Fry to discuss a 1909 warning about technology, and listens to reflections on the digital age from experts such as historian Mary Beard (pictured) and social psychologist Aleks Krotoski.
Available now, BBC Sounds

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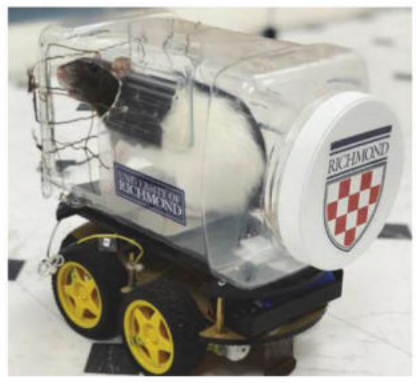

Learning to drive a tiny car reduces stress levels in rats. Just wait until they get on the M25...

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A new study has discovered that heading the ball might be putting footballers at risk of dementia.

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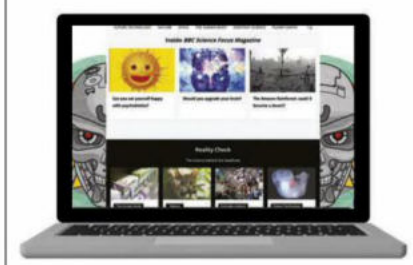
Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied.
sciencefocus.com



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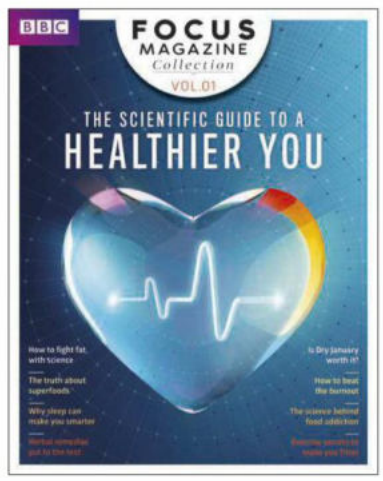

THE SCIENTIFIC GUIDE TO A HEALTHIER YOU
In this special edition, brought to you by the team at *BBC Science Focus*, we investigate how to fight fat with science, we also discover the truth about superfoods, find out why sleep can make you smarter, and ask whether Dry January is worth it.
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EYE OPENER

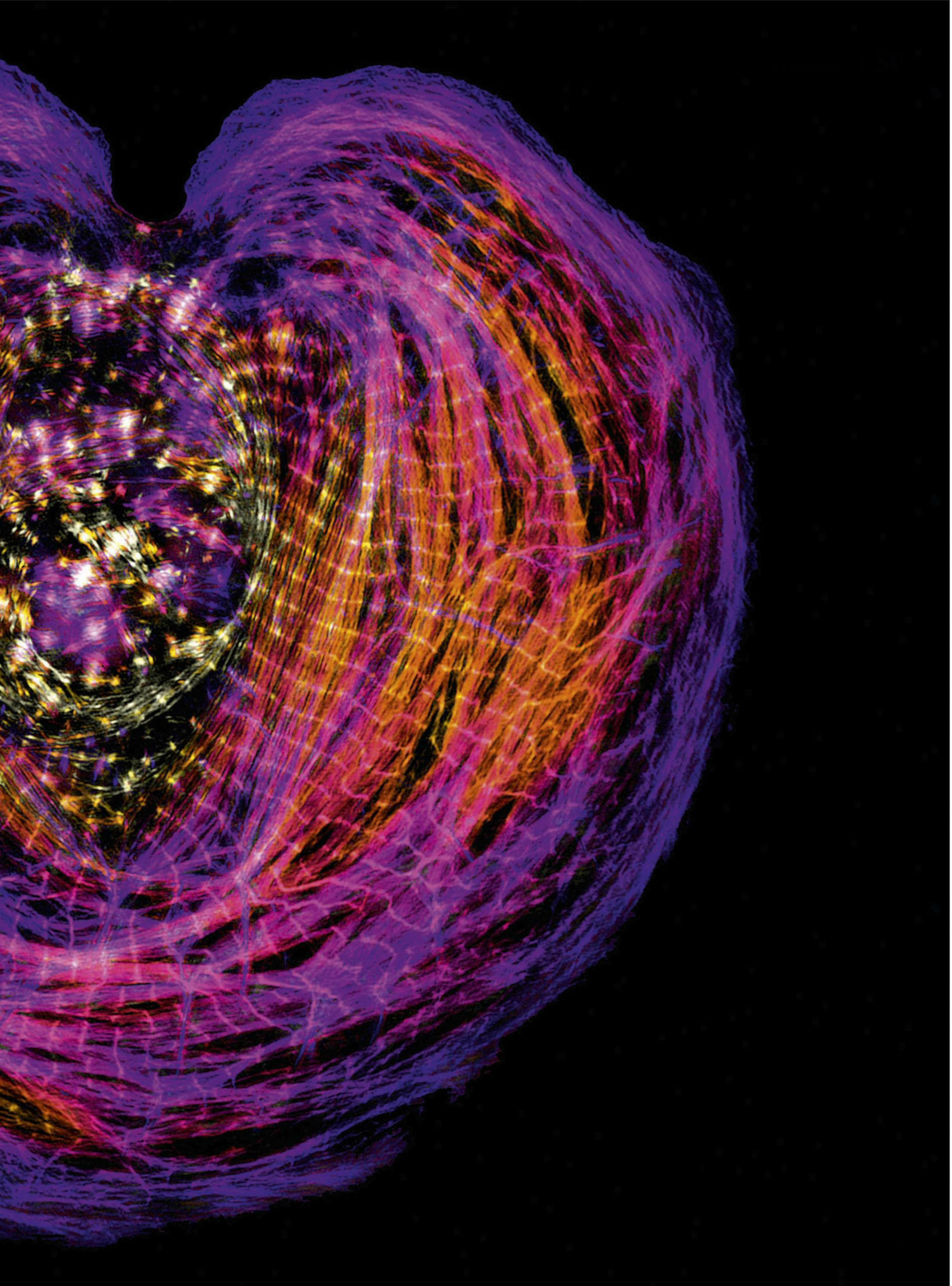
Beat it

TENNESSEE, USA

This photo of a cardiomyocyte cell, taken by graduate student Abigail Neininger and Dr Dylan Burnette at Vanderbilt University, was an image of distinction in the Nikon Small World photo competition. These cells are located in heart muscle, and the visible strands are fibres called sarcomeres. Each contains filaments of actin and myosin proteins, which work together to contract the cardiomyocytes, causing the heart to beat.

Neininger used a toxin called phalloidin to stain the cell and reveal its structure. The team hopes to discover how sarcomeres form, so they can one day rebuild cells that have been damaged by disease. "Cardiomyopathies, diseases of the heart muscle, affect sarcomeres," says Neininger. "If we understand how those contractile systems form in the first place, we might be able to understand more about those diseases."

ABIGAIL NEININGER/NIKON



EYE OPENER

Lake energy

VALAIS, SWITZERLAND

A new project led by Romande Energie hopes to provide 220 homes in Switzerland with power from solar panels on the Lac des Toules alpine reservoir. Unveiled in October, the floating solar panels cover 2,240m^2 of the lake. They were engineered to withstand the extreme local weather, facing wind, snow and ice.

The artificial lake is already home to a hydroelectric dam. As winter comes to an end, the reservoir will be empty, but the solar panels will still be able to provide power as they lie flat on the lake bed. When the lake fills in the spring, it is hoped that the panels will float on the rising water. "This pilot project allows us to run environmental studies to see if there are any impacts on the environment, and which mitigation measures should be implemented if we realise a bigger project," says Guillaume Fuchs, project manager at Romande Energie.

SHUTTERSTOCK

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

Generation rage

Since I started subscribing to *Science Focus*, as a 15th birthday present earlier this year, I've read a lot of articles relating to climate change. Recently, my friend's mum complained that we were all looking at our phones while in the car. She launched into an attack, quickly finding a YouTube video as ammunition. She made us all listen to a venomous letter from an older person, criticising young people for striking against climate change, while commenting that we should all stop using technology 24/7 and go back to school! It really angered me as we weren't the ones that invented all the technology today, any more than we were responsible for the enormous destruction of the Amazon rainforest that has already occurred.

Older people should be sympathetic to us trying to ensure that we and the planet have a future! Blaming each other isn't going to solve the crisis, it's time for action, not blame.
Joey Cooke, *via email*

WRITE IN AND WIN!
The writer of next issue's *Letter Of The Month* wins an **EZVIZ Wi-Fi Indoor Smart Security Cam.** This indoor security camera boasts 1080p full HD and a 130° wide angle lens to help keep your home safe. It has infrared vision, so even dark corners will still be visible. The camera will send an alert to your phone if it detects any motion, and has two-way communication so you can chat to family while you're away or deter any intruders.
ezvizlife.com

An educated population

I would like to comment on the excellent article 'Overpopulation: the debate' (September, p74). When given a choice, most women would not have large families. My grandmother had 10 children. Two died in infancy, one never married and the rest went on to have between one and three children per family. This same pattern occurs in most countries: the number of children per family drops once women can be in charge of their reproductive options. Educating girls and family planning is important for tackling climate change, but also for eliminating poverty, abuse of women and child labour. My grandmother often complained that, "My whole life I was either pregnant or with baby at the breast!" However, my father was her latest surviving child – if she had contraception neither he nor I would have been around!
Elena Holden, *via email*

A puff of inspiration

Your smoke ring cannon (October, p83) reminded me of a lecture at university, where the visiting speaker demonstrated how a toroidal vortex, produced by suddenly expelling air through a circular hole, propels itself and can extinguish a candle flame. In a moment of enthusiasm, I cut a 10cm diameter hole in the bottom of an old-style, round plastic dustbin, and covered the open end with a foam sheet. A sudden blow to the sheet created a vortex that could extinguish a candle flame 10m away, if the aim was right.
Richard Gregory, *via email*

Sound familiar?

In your article on mass extinction (August, p48), it says that the End-Permian event was caused by massive volcanic eruptions in Serbia. That should be Siberia. Apparently, the eruption incinerated massive coal beds, hence the huge spike in CO_2 that acidified the oceans and wiped out marine life. For some reason that scenario sounds familiar, doesn't it?
Malcolm K Cleaveland, *via email*

Consider this

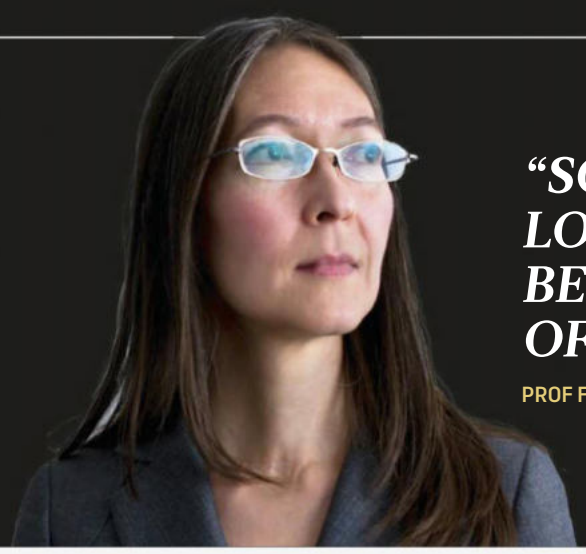
I was interested and disappointed in Dr Roger Tyers's piece concerning flying emissions (October, p38). Such problems are often far more complex than he suggests. I would accept that we do not have to have strawberries all year round in the UK, but for the farmers producing them the contract may represent their whole livelihood.

Whether we like it or not, we live in a globally integrated society that provides benefits across the world. Air transport is the facilitator – the whole system could not function without it. We must find more realistic solutions to solve the problem, not by assuaging the consciences of rich countries with carbon offsetting and 'no flying' campaigns since these may be to the detriment of poorer countries.
Dr Philip Shearman, *Cheltenham*

Oops...

In the November issue, *Innovations* (p47) listed the Oculus Quest's price at £4.99. It should have said £499.

Also in the November issue, a couple of errors snuck into the oceans feature (p49) during the editing process. It said that the oceans have become 300 per cent more acidic since pre-industrial times. This should have said 30 per cent. Also, oceanic plankton produces around 50 per cent of the Earth's oxygen, not up to 85 per cent.



"SCIENCE ADVANCES BY LOOKING AT CONTRADICTIONS BETWEEN DIFFERENT PIECES OF OUR UNDERSTANDING"

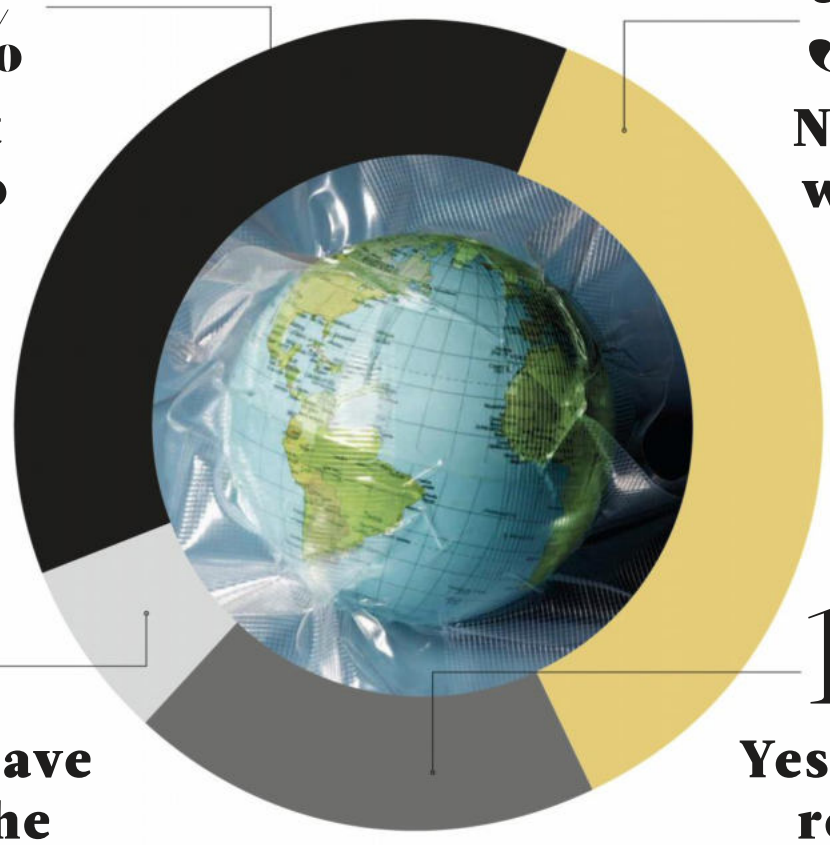
PROF FAY DOWKER, p74

READERS' BUZZ

Your views on the burning science topics of the month

Campaigners have taken to streets around the globe this month to raise awareness of the climate emergency. November's *Reality Check* investigated whether non-violent movements are the best way to raise public awareness of a cause. We asked *BBC Science Focus* followers on Twitter:

HAVE YOU TAKEN PART IN A CLIMATE CHANGE PROTEST?



37% No, but hope to in the future

37% No, it's a waste of time

7% Yes, I have since the beginning

19% Yes, I have recently joined in

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ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £63; Europe & Eire Airmail £66;
Rest of World Airmail £70.

Audit Bureau of Circulations
50,022 (combined; Jan Dec 2018)

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IMAGE TAKEN BY UK X-PHOTOGRAPHER MARIANNE CHUA

DISCOVERIES

LEARNING TO DRIVE CAN LOWER STRESS LEVELS IN RATS

For many of us, learning to drive is not a particularly pleasant experience. Being behind the steering wheel for the first time and not knowing exactly how to control it is likely to be up there as one of the most stressful things we've ever done. Not so for rats, it seems. Researchers at the University of Richmond in the US have found that learning to drive actually helps the rodents to feel more relaxed.

Using food treats as a reward, the team trained a group of 17 rats to drive tiny cars. They built the cars by fixing a clear plastic jar onto a wheeled aluminium base containing an electric motor. They then created a ➤

The rats were trained to operate tiny cars to get food rewards

UNIVERSITY OF RICHMOND

I heart you Dogs could help heart attack survivors live longer p24 **Babies in space** A company outlines its plans for births beyond Earth p26
First female-only spacewalk In pictures... p28

News in brief

BANNING FIZZY DRINKS

Removing sugary drinks from workplace vending machines and cafeterias can help staff lose weight and decrease waist size, researchers at the University of California, San Francisco, have found. Before a workplace ban, each person in the study consumed about a litre of sugary drinks a day on average – around three cans of cola. Though participants were allowed to bring in fizzy drinks from home, the study found that, after 10 months of the on-site sales ban, average consumption had nearly halved. Even participants who were not overweight lost belly fat when they cut their consumption. As high sugar intake is linked to health problems like diabetes, heart disease and cancer, swapping fizzy pop for water in the office could help in the fight against these illnesses.

Prof Kelly Lambert found that rats were less stressed as a driver than as a passenger

‘steering wheel’ by threading a copper wire across the front of the car to form three bars: one on the left, one in the middle, and one on the right. To drive the car, the rats simply had to sit on the aluminium plate and touch one of the copper bars to complete the circuit and move the car in the desired direction. After a few months, the rats had mastered the technique and could drive across an enclosure to collect treats.

After the tasks had been completed, the researchers measured the levels of stress hormones in the rats’ faeces. They discovered that the act of driving the mini ratmobiles had a calming effect on the rodents.

“When we measured hormones associated with stress, corticosterone; and resilience, DHEA, in their poop, we found that the training itself changed the hormones in a healthy trajectory [higher DHEA/CORT ratios]; therefore, we found that driving training led to more resilient stress hormone profiles,” said Lambert.

“When we measured hormones associated with stress, the training changed the hormones in a healthy trajectory”

The same stress-relieving effect was not seen in rats that had ridden in the cars as passengers.

As rat brains contain all of the same areas and neurochemicals as human brains, albeit in a smaller package, investigating the changes that occur when they carry out specific tasks could provide a model for studying the negative impact of chronic stress and how it compromises mental health in humans, the researchers say.

The team is now planning further experiments to determine how the brain changes when learning the driving skill and how mastering new tasks affects rats’ stress responses and ability to cope with new challenges.

They did what?

Monkeys' accents analysed

WHAT DID THEY DO?
Researchers at the University of Zurich listened in on the calls of a group of common marmosets before and after they moved to join a new colony, looking for signs that the nature of the calls changed after the move.

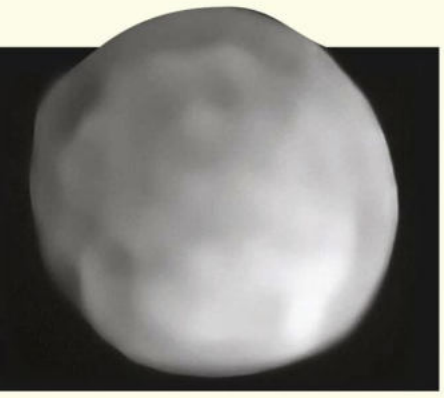
WHY DID THEY DO THAT?
It was previously known that marmosets from different colonies communicate with different calls, or 'accents'. However, the researchers were unsure if these different accents were due to genetic or environmental factors.

WHAT DID THEY FIND?
Once embedded within the new colony, the marmosets quickly began to change their accents to match that of their new friends. It is not entirely clear what the benefits of learning a new accent are but, like as the famous Fred Astaire and Ginger Rogers song *Let's Call The Whole Thing Off* suggests, marmosets with matching accents may have a better chance of finding mates, the researchers say. You say potato, I say potahto indeed.

UNIVERSITY OF RICHMOND, DAVID HARING/DUKE LEMUR CENTER, GETTY IMAGES, ESO ILLUSTRATION: CHIARA BRAZZALE

'ASTEROID' MAY BE THE SOLAR SYSTEM'S SMALLEST DWARF PLANET

Nestled in the enormous asteroid belt between Mars and Jupiter is the space rock Hygiea. It was discovered back in 1849 and is the fourth largest object in the belt after Ceres, Vesta and Pallas. But now, astronomers at the Very Large Telescope (VLT) in the Atacama Desert think that Hygiea is not an asteroid but could actually be classified as a dwarf planet.

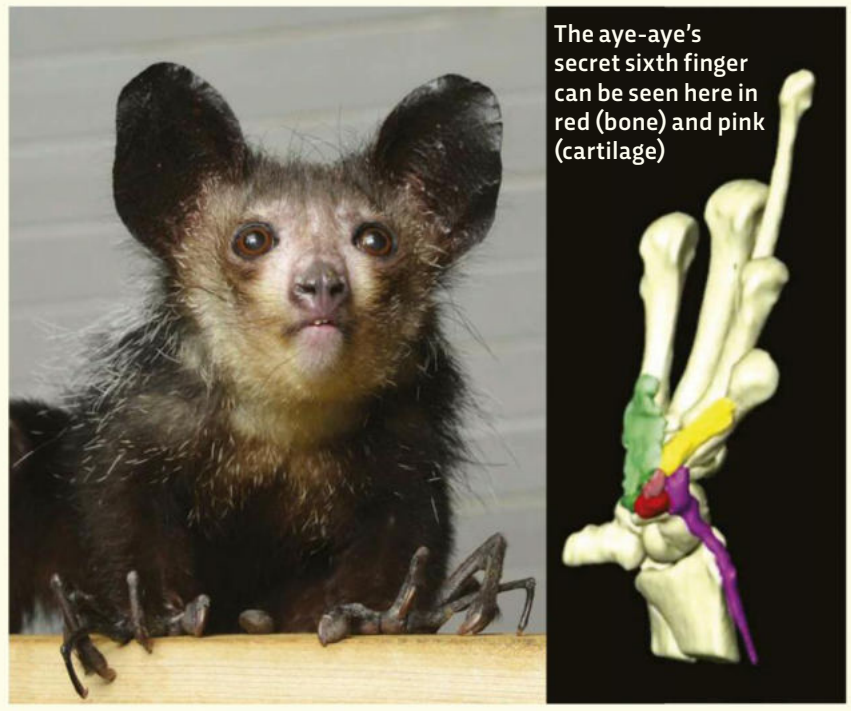


ZOOLOGY

Aye-aye is the first primate with a sixth finger

One of the world's weirdest animals just got a little bit weirder. The aye-aye – a nocturnal, Madagascan lemur with satellite-dish ears and dinner-plate eyes – is now the first known primate to have a sixth finger.

This tiny extra digit – called a 'pseudothumb' – is a structure on each wrist made of bone and cartilage. It is believed to have evolved to help the lemur grip branches as it climbs through the trees.



The aye-aye's secret sixth finger can be seen here in red (bone) and pink (cartilage)

"The aye-aye has the craziest hand of any primate," said study leader Dr Adam Hartstone-Rose, a biologist and anatomist at North Carolina State University.

Most famously, the lemur's hand sports an elongated middle finger, which it uses to tap against trees to find grubs, locating hollow areas by listening for the echoes.

Now, Hartstone-Rose and his team have discovered an extra structure, which they noticed when studying the tendons in the aye-aye's hand.

To examine the structure in more detail, they dissected six aye-aye specimens and used digital imaging to visualise the pseudothumb in 3D, finding that it is attached to three distinct muscles.

"The pseudothumb can wriggle in space and exert an amount of force equivalent to almost half the aye-aye's body weight," said Hartstone-Rose. "So it would be quite useful for gripping.

"Other species, like the panda bear, have developed the same extra digit to aid in gripping, because the standard bear paw is too generalised to allow the dexterity necessary for grasping."

The researchers believe that the aye-aye, on the other hand, developed this digit to compensate for its other, *overspecialised* fingers.

"Some other primate species have reduced digits to aid in locomotion," said Hartstone-Rose. "The aye-aye is the first primate to dial digits up in the hand rather than dial them down. And it's amazing that it's been there the whole time, in this strangest of all primates, but no one has noticed it until now."

SLOWER WALKERS HAVE 'OLDER' BRAINS

The walking speeds of middle-aged people can be used as an indicator of their biological age – a measure of how well their bodies are functioning relative to their actual age. A long-term study of nearly 1,000 people aged 45 carried out in New Zealand, has found that slower walkers tend to have lower total brain volume, less brain surface area and more damage to the brain's white matter. The slower walkers were also judged to have older-looking faces.

Trending

YOUR GUIDE TO WHO'S SAYING WHAT ABOUT THE HOTTEST TOPICS IN THE WORLD RIGHT NOW

#AlexeiLeonov

The first ever person to walk in space, the Russian cosmonaut Alexei Leonov, passed away 11 October aged 85. He made history in 1965 when he performed the first spacewalk, floating freely in space for more than 12 minutes.

Scott Kelly
@StationCDRKelly

Cosmonaut #AlexeiLeonov passed away today in Moscow. He was not only the first person to walk in space, but also an accomplished artist. Most significant, however, he was a great human being. Fair winds and following seas my friend. #RIP

Garrett Reisman
@astro_g_dogg

We lost a most remarkable man today. #alexeileonov I still treasure every moment that I spent with him not only because of his superhuman accomplishments in space and his most singular life, but because he was a kind, humble, warm, and funny human being.

#Inhalers

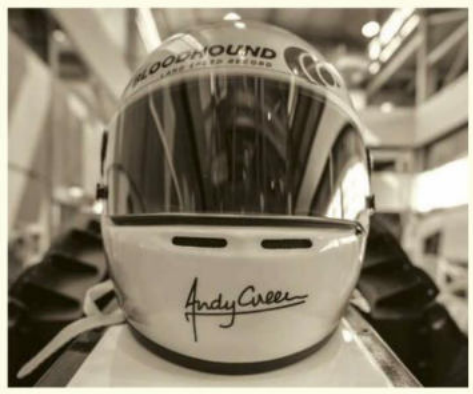
Many inhalers for conditions like asthma contain greenhouse gases known as hydrofluoroalkanes (HFAs). A study from the University of Cambridge claims that switching to dry powder inhalers could cut the carbon footprint of the NHS by up to 4 per cent.

Lauren Couchman
@laurencouchman1

If you are an asthma sufferer please follow the advice of @asthmauk and consult a nurse or doctor before changing any medication! Don't feel guilty for using medication that is keeping you alive! #asthma #inhalers #dontstop #seeadoctor

Diary of a Disabled Person
@WheelsofSteer

Oh, I'm sorry, I'll just go die of an asthma attack then. First you want to stop #disabled people from drinking, now you want us to stop breathing. 'Cleaner' inhalers don't work. We will die. Stop trying to find excuses to vilify disabled people & kill us.



#BloodhoundLSR

The Bloodhound supersonic car has begun preparations to take on the land speed record in South Africa. In preliminary tests the vehicle has reached 612km/h (380mph). The current land speed record stands at 1,228km/h (763mph).

FIA
@fia

#LandSpeed – Fantastic progress being made with #2019HST at #Hakskeenpan #bloodhoundlsr #landspeedrecord

Iain Gray
@iain_gray

Fantastic stuff ... keep up the progress – what speed can you achieve by November 6th #thisisengineeringday

AVM 'Bunny' James
@RAFGender

All the very best for the rest of testing. Exciting times and an inspiration to #nextgen

#DeepMind

Google's DeepMind AI has reached Grandmaster level at the online game *StarCraft II: Wings Of Liberty*, using its AlphaStar program. This achievement puts it in the world's top 200 players.

Ramin Parker
@MyRetroFuture

AlphaStar is the first AI to reach the top league of a widely popular esport without any game restrictions. Congratulations!

Alex Bagnall
@AlexBagnall

AI will be used to train #eSports superstars of the future and lead to the discovery of new game strategies, playstyles, and genres #DeepMind #AI

KEEP IN TOUCH

@SCIENCEFOCUS

PSYCHOPATHS

Psychopathic traits such as risk taking, overconfidence and superficial charm can make men more attractive to romantic partners, despite them having little interest in committed relationships, researchers at Canada's Brock University have found.

NARCISSISTS

People who harbour feelings of grandeur are less likely to get stressed or depressed, a study at Queen's University Belfast has found. Narcissists consider themselves superior to others, and show little empathy, shame or guilt – 'qualities' that appear to shield them from negative effects of stress.

Good month

Bad month

EARLY RETIREES

The thought of sacking off your job and collecting your well-earned gold watch early in life may sound like a dream to many, but early retirement can also lead to accelerated cognitive decline, a study at Binghamton University in New York has found.

BEARDED MEN

Gearing up for an interview for your dream job? You might want to break out the shaving cream. A study of more than 1,000 job applicants carried out at Rollins College in Florida has found that men with beards are deemed to be lacking in warmth compared to their less hirsute counterparts.

GETTY IMAGES X3, BJORN CHRISTIAN TORRISSEN/WIKIPEDIA ILLUSTRATIONS: CHIARA BRAZZALE

Saharan silver ants emerge in the heat of the day to feast on the corpses of dead animals

ZOOLOGY

Get that ant a medal

The Saharan silver ant has joined the list of record-breaking animals, as researchers from the University of Ulm in Germany have found it is able to run at speeds of 855mm/s – or 108 times its own body length per second – making it the world's speediest ant. To put that into perspective, when Usain Bolt set the world record for the 100m sprint, he ran at 5.35 times his body height per second.

The ant's impressive speed comes from the fact that it must be fast enough to survive its travels across the blisteringly hot sand. At midday in Douz, Tunisia, while other animals seek shelter, the Saharan silver ant takes advantage of the lack in predators to scavenge the corpses of dead animals. The surface temperatures in the desert can reach a scorching 60°C, but the ant is only able to tolerate a body temperature of up to 53°C, so the insect needs to regularly dash back to its underground nest to cool down between foraging expeditions.

To find out how fast the ants are and how they achieve their rapid pace, the team filmed the ants in the desert, and also recorded them running more slowly at cooler conditions in the lab. They discovered that although the ant's legs are almost 20 per cent shorter than another Tunisian ant of the same genus, the silver ant's footwork is much more impressive, taking 47 strides per second. At high speeds, it can even take all six of its feet off the ground to gallop across the desert sand. When its feet do touch the ground, it is for as little as seven milliseconds. "These features may be related to the sand dune habitat," said Dr Harald Wolf, who took part in the study. "[They] could prevent the animal's feet from sinking too deeply into the soft sand."

Wolf wants to carry out even more research into the ants, as he thinks that their muscles may even be working at close to physiological limits, in order to pull off their speedy feats.

POTENTIAL EMPLOYERS SHOW CLASS BIAS AFTER LISTENING TO INTERVIEWEES FOR A FEW SECONDS

You'd expect job interviewers to judge you on your attitude and experience, but new research suggests they could be critiquing your speech too. Employers can accurately judge an interviewee's socioeconomic status after hearing them say just seven words, researchers at Yale University have found. This can affect their perception of the interviewee and can even lead to them offering a better starting salary to those deemed to be higher in social class.

In numbers

18 PER CENT

The number of species of vertebrates that have been traded on wildlife markets.

30 YEARS

The time frame in which humans will find evidence of alien life, according to Nobel Prize-winning astronomer Prof Didier Queloz.

22 HOURS

The amount of time koalas spend asleep each day, in order to digest their diet of eucalyptus leaves.

HEALTH

An apple a day keeps the blues at bay

Three weeks is all it takes for dietary changes to reduce the symptoms of depression, according to a small Australian study. Young adults with depression whose diets contained high amounts of processed foods, sugar and fats, exhibited significantly fewer signs of depression after 21 days of consuming more fruit, vegetables, fish and lean meats.

> **"An increased consumption of fruit, veg, fish and olive oil improved depression"**

Psychologist Dr Heather Francis and her colleagues at Macquarie University in Sydney, studied 76 students aged 17 to 35 with poor diets who exhibited moderate to high symptoms of depression. The students were randomly split into two groups: one in which the students continued with their existing diets; and another that received advice on diet, along with a hamper of healthy foods and AU$60 (£33 approx) towards groceries.

The people on a healthy diet, rich in fruit, veg, whole grains, nuts and olive oil, reported boosts in their mood

The researchers assessed each student for depression, anxiety and overall mood before and after the three-week test period, and also rated their performance on several learning and reasoning tasks. At the end of the three weeks, the healthy eating group showed significant improvement in mood, with depression scores dropping into the normal range. Scores for the students who stuck to eating unhealthily remained in the moderate-to-high range. The healthy diet group also showed significantly lower anxiety scores than the unhealthy diet group, though other measures were not significantly different between the groups.

The researchers checked in with 33 of the students three months after the test and found that while only 21 per cent of them stuck with the healthy diet, those that did managed to maintain their improvements in mood.

"Modifying diet to reduce processed food intake and increase consumption of fruit, vegetables, fish and olive oil improved depression symptoms in young adults," said the study's authors. "These findings add to a growing literature showing a modest change to diet is a useful adjunct therapy to reduce symptoms of depression."

GETTY IMAGES X3

ZOOLOGY

Cull drives badgers to roam further

The ongoing badger cull to contain tuberculosis may not be having the desired effect

The controversial badger cull, intended to reduce the chances of the animals spreading bovine tuberculosis, may be having the opposite effect, according to new research. Carried out jointly by Imperial College London and the Zoological Society of London (ZSL), the research shows that surviving badgers roam across a much wider area after a cull, potentially increasing the transmission of bovine TB.

"As badger-to-cattle transmission is likely to occur through contamination of their shared environment, and TB bacteria can remain viable for long periods of time, the effects of increases in ranging behaviour could create a source of infection for several months – long after the individual badger has been culled," said Prof Rosie Woodroffe of the ZSL. "In contrast, studies have shown that vaccination prompts no changes in badgers' ranging behaviour."

The researchers studied 67 badgers across 20 Cornish cattle farms in areas with and without farmer-led culling, collecting GPS-collar data between 2013 and 2017. Their study revealed that a cull drives badgers to cover 61 per cent more land each month than they did before.

Badgers were also found to visit 45 per cent more fields each month, and the odds of a badger visiting neighbouring territories each night increased 20-fold – potentially increasing the risk of TB transmission to both cattle and other badgers.

The researchers think that the culls remove certain badgers from established territories, opening them up to those that survive. Interestingly, the badgers that survive a cull spend on average 91 minutes less per night outside their sett. ZSL scientists believe this could be linked to reduced competition and increased food availability, as rival badgers are removed from the population.

Data crunch

THE SCALE OF LIFE

One of the most fundamental projects in biology is to describe the composition of the entire living world. A team from Rutgers University in New Jersey used local biomass and then extrapolated the data to find a global estimate.

INFOGRAPHIC BY VALENTINA D'EFILIPPO

Each leaf represents the total mass of a kingdom of life in gigatons of carbon (Gt C). All biomass on Earth is dominated by plants – which combined are 7,500 times more massive than all the humans.

PLANTS
450 Gt C

HUMANS
0.06 Gt C

BACTERIA
70 Gt C

Bacteria are the second most numerous type of life on Earth with a biomass that's 35 times larger than that of the animal kingdom. Fungi, archaea (single-celled organisms somewhat similar to bacteria), and protists (microscopic life such as amoebae), also outweigh the entire animal kingdom.

FUNGI
12 Gt C

ARCHAEA
7 Gt C

PROTISTS
4 Gt C

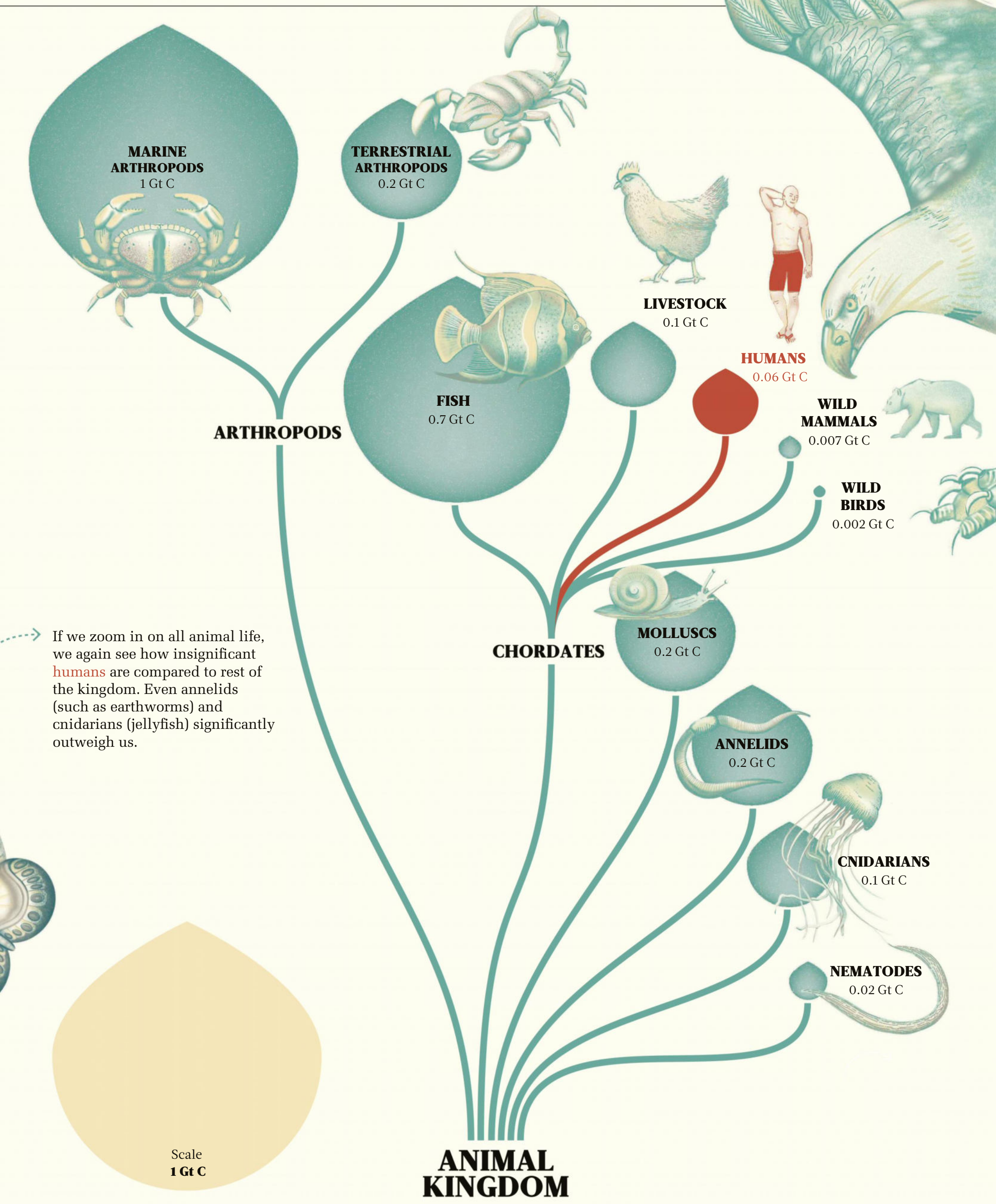
ANIMALS
2 Gt C

VIRUS
0.2 Gt C

Scale
1 Gt C

KINGDOMS OF LIFE

Source: The biomass distribution on Earth
Yinon M. Bar-Ona, Rob Phillipsb, and Ron Miloa



If we zoom in on all animal life, we again see how insignificant humans are compared to rest of the kingdom. Even annelids (such as earthworms) and cnidarians (jellyfish) significantly outweigh us.

GREEN PAPERS

The environmental stories you need to know

Words: **Jocelyn Timperley**

EBOLA SCARE

Ebola outbreaks are set to increase in several African countries as greenhouse gas emissions rise, according to new research published in the journal *Nature Communications*. The study examined a set of "plausible future environments" of different degrees of climate change and poverty alleviation, and found a large difference in how Ebola responds to the best- and worst-case scenarios. "Ebola risk appears to worsen in future versions of our planet that have higher climate change and worse cooperation between societies," said Kate Jones, professor of ecology and biodiversity at University College London (UCL). The latest epidemic has killed more than 2,100 people since August 2018.

ABOVE Drug traffickers, fearing arrest, hide out in protected forests, where they chop down trees to create land for airstrips, illegal ranching and farming

DEFORESTATION

'War on drugs' is driving deforestation

Military action is pushing criminals into protected areas

Drug trafficking and the corresponding 'war on drugs' are driving deforestation in Central America, two new reports published by Fundación Neotropica and the PRISMA Foundation think tank have found.

Military efforts to tackle cocaine traffickers have instead pushed them into remote forests, where the shadowy underground economy they build has a devastating effect on the environment, the researchers said. The economic impact on the region's protected forests is at least $215m per year, they found.

The researchers took remote satellite images to locate where deforestation is occurring, and carried out nearly 100 interviews with local protected area managers, residents and non-profit leaders. They found that large

THE US BACKS OUT ON PARIS ACCORD

President Trump has confirmed plans to begin withdrawing the United States from the Paris climate accord. He made the announcement at an energy conference in Pittsburgh, where he argued the agreement would shut down US producers. Trump has repeatedly described the Paris accord as a bad deal for the US. The president announced his intention to pull out from the Paris accord in June 2017. However, the first date the country can make a formal request to exit is 4 November 2019. The pull-out would then take effect a year later – the day after the 2020 US presidential election – assuming that Trump is re-elected.

tropical forests in Guatemala and Honduras are particularly affected, while Nicaragua, Panama and Costa Rica are also impacted.

The problem has become worse as the current US government has moved towards investing 'war on drugs' money into military rather than humanitarian aid, said Jennifer Devine, assistant professor of geography at Texas State University and co-author of the two studies.

"Military approaches to solve the problem of drug trafficking have pushed traffickers who want to evade drug seizures into remote, isolated areas which are often protected areas, and forests in particular," she said.

The traffickers then clear forests to create hundreds of air strips to land planes full of cocaine coming from the Andes. Drug traffickers also deforest protected lands to launder drug money, through industries such as illegal cattle ranching and palm oil production, said Devine.

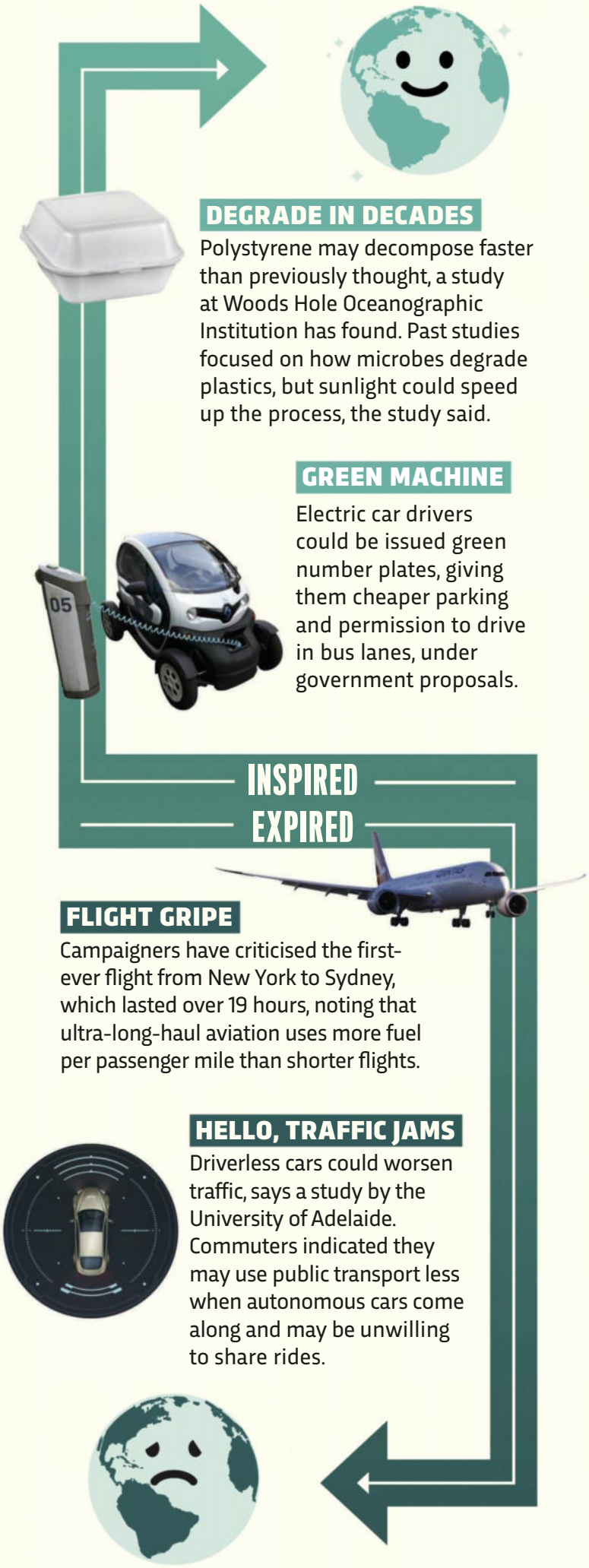
The papers highlight the profound costs driven by drug deforestation, said Andrew Davis, director of the Forest and Territorial Governance Program of the PRISMA Foundation. "They also underscore a recognised but under-reported fact, that drug trafficking and interdiction policy is contributing to climate change," he said.

According to the researchers, the focus should be on having protected areas managed by local communities and community-based organisations. These tend to fare much better than the national parks managed by the state which are supposed to be "people-less", added Devine.

"The solution to this problem is to rethink approaches to the war on drugs," she said. "I think that few people fully appreciate that the war on drugs is driving environmental crisis in Central America."

A previous study published in 2017 found that cocaine trafficking was responsible for 30 to 60 per cent of deforestation in Central America's protected areas in the previous decade.

"Few people fully appreciate that a war on drugs is driving environmental crisis in Central America"



DEGRADE IN DECADES

Polystyrene may decompose faster than previously thought, a study at Woods Hole Oceanographic Institution has found. Past studies focused on how microbes degrade plastics, but sunlight could speed up the process, the study said.

GREEN MACHINE

Electric car drivers could be issued green number plates, giving them cheaper parking and permission to drive in bus lanes, under government proposals.

INSPIRED
EXPIRED

FLIGHT GRIPE

Campaigners have criticised the first-ever flight from New York to Sydney, which lasted over 19 hours, noting that ultra-long-haul aviation uses more fuel per passenger mile than shorter flights.

HELLO, TRAFFIC JAMS

Driverless cars could worsen traffic, says a study by the University of Adelaide. Commuters indicated they may use public transport less when autonomous cars come along and may be unwilling to share rides.

IT'S EASY BEING GREEN

DITCH THE TAMPON

Around 4.3 billion items of disposable sanitary towels and tampons are used each year in the UK. This adds up to an estimated 200kg of waste over a person's lifetime, much of it plastic. This ends up in landfill or, even worse, flushed down the toilet into the ocean. There are other options, however. Menstrual cups are devices made from flexible silicone which collect menstrual fluid and can be reused for up to 10 years. They are a safe alternative to tampons, a recent Lancet Public Health study found. Reusable cloth pads and 'period pants', which absorb fluid just like disposable pads but can be washed, are also good.

GETTY IMAGES X6

DOGS ARE A HEART'S BEST FRIEND

Dogs may help survivors of heart attacks and strokes live longer, according to a study and a separate analysis of more than 3.8 million stroke and heart attack patients, published in the journal *Circulation: Cardiovascular Quality And Outcomes*. Compared with patients who live alone, risk of death was 24 per cent lower for patients with a pooch. The findings don't prove that owning a dog leads to longer life, but dogs may reduce risk factors for cardiovascular diseases, as owners get more exercise, have lower blood pressure and are less isolated.

HAPPINESS

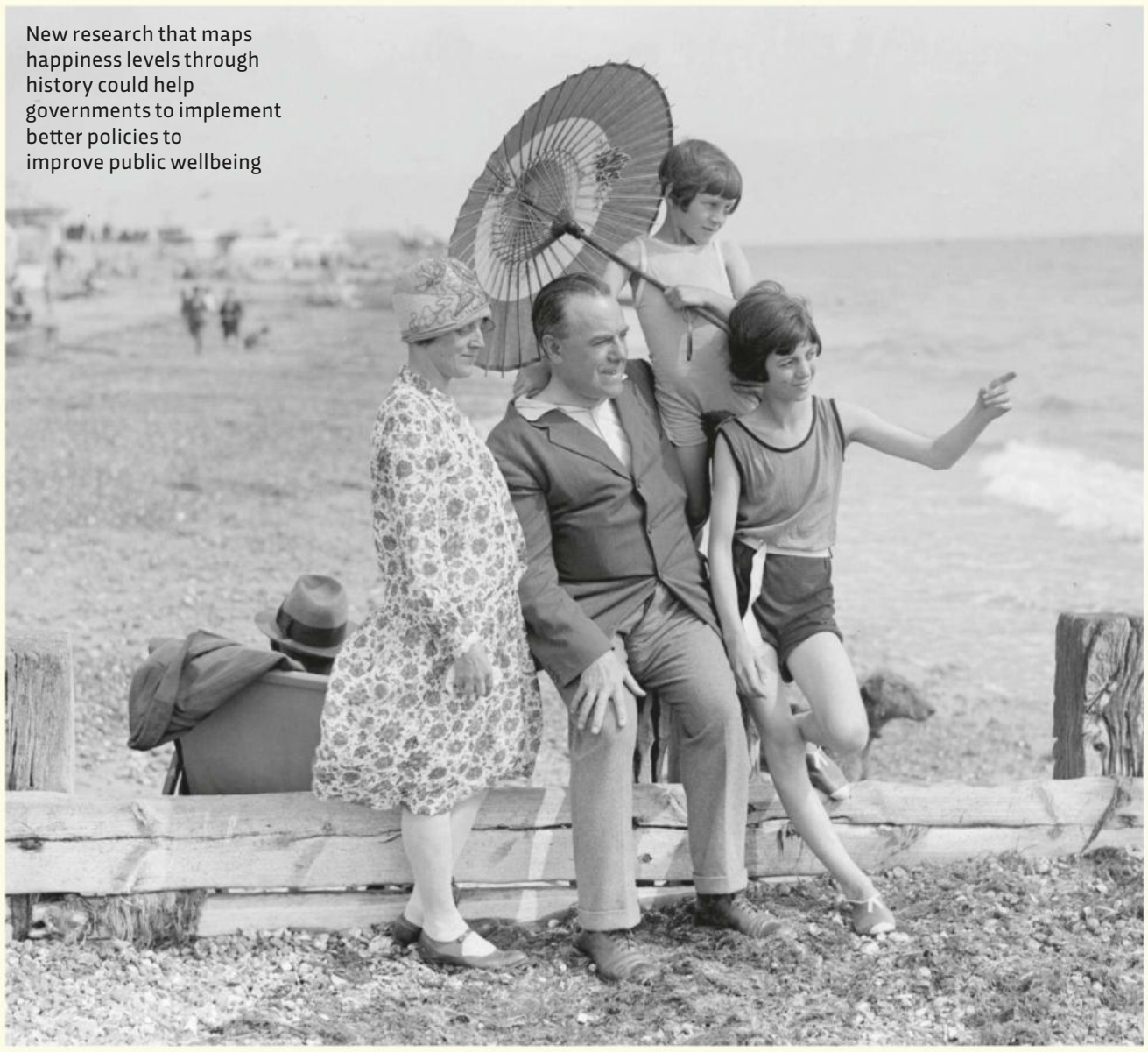
National happiness mapped over the last 200 years

Governments around the world are increasingly trying to measure people's happiness levels so they can find out how their policies affect wellbeing. However, 'happiness' data is generally only available from the last decade, which makes it difficult to study long-term trends or to find out what made people happy in the past.

Now, scientists from the University of Warwick, the University of Glasgow and the Alan Turing Institute in London may have found a way to establish historical happiness levels by studying millions of books and newspapers published from 1820 to 2009. According to psychological theory, you can gain an understanding about people's emotions through what they say or write, with publications reflecting the national mood.

In order to carry out the analysis, the main source of the language information came from Google Books corpora, which contains word frequency data for eight million books. The researchers' method calculated the values of happiness that can be derived from text – for thousands of words in different languages – to establish the relative proportion of positive and negative language for four different nations (the US, UK, Germany and Italy) through history.

This new method was compared to current survey-based measures and was found to be an accurate way to establish national mood. By studying the data, the researchers could see peaks and troughs in happiness over time, which often corresponded with key events, like the end of rationing, or recessions.



New research that maps happiness levels through history could help governments to implement better policies to improve public wellbeing

GETTY IMAGES X2

"Subjective wellbeing is incredibly resilient to wars"

"What's remarkable is that national subjective wellbeing is incredibly resilient to wars. Even temporary economic booms and busts have little long-term effect. We can see the American Civil War in our data, the revolutions of 1848 across Europe, the roaring 20s and the Great Depression. But people quickly returned to their previous levels of subjective wellbeing after these events were over," said Prof Thomas Hills, who took part in the research.

The researchers also used the data to establish some interesting findings. For example, they found that one less year of war had an equivalent effect on happiness of a 30 per cent rise in GDP, and in post-war UK, the unhappiest period was the Winter of Discontent in 1978-1979.

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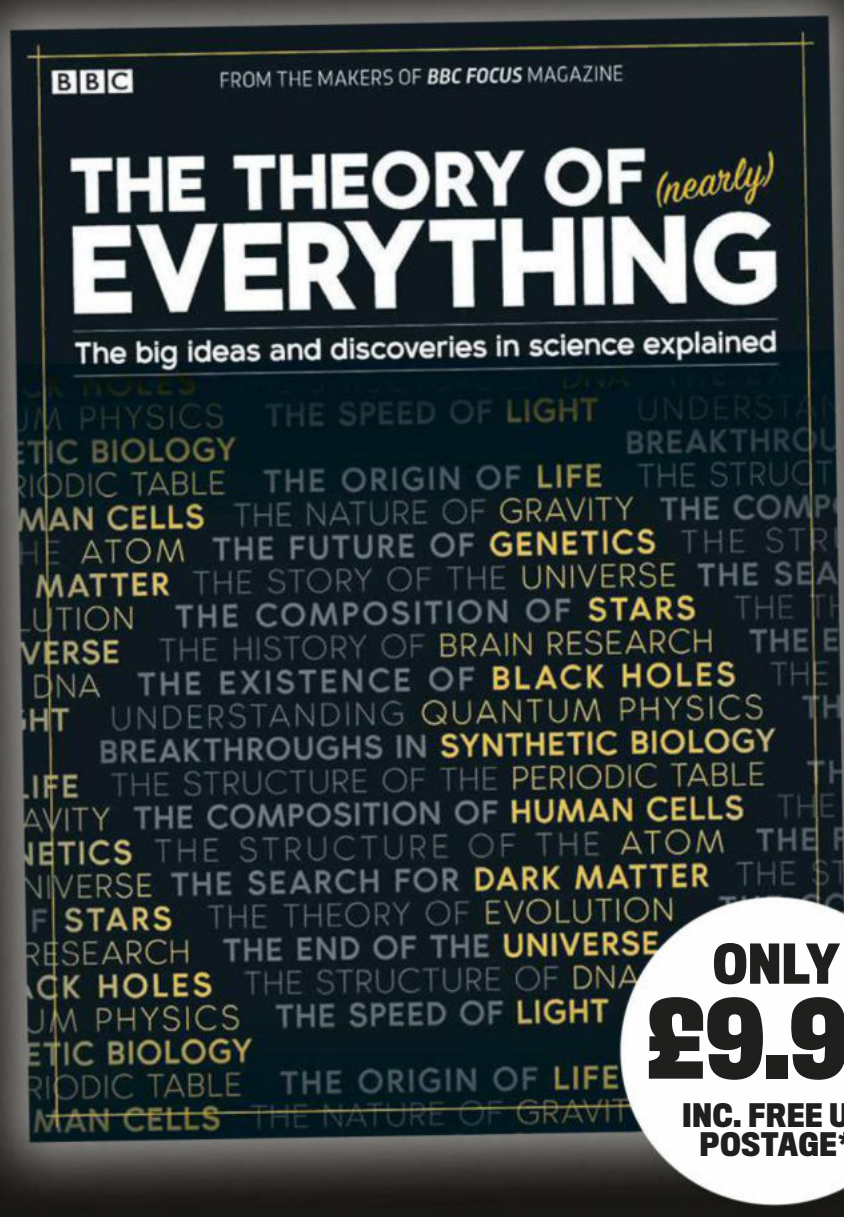

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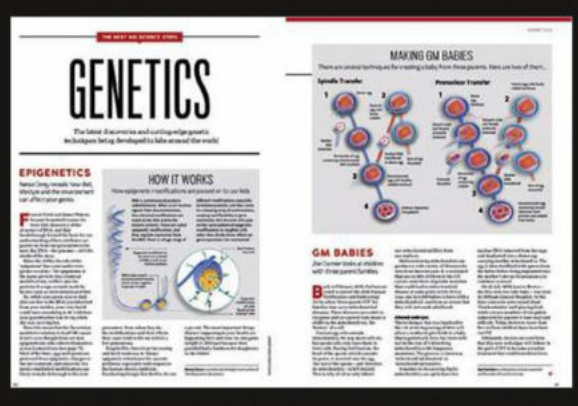

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Dr Egbert Edelbroek scientist and entrepreneur

Horizons

Quest for the first space baby

The first child could be born in space within 15 years, says Dr Egbert Edelbroek, founder and chief executive of SpaceBorn United, a research organisation dedicated to making that happen

WHAT'S THE MOTIVATION FOR DELIVERING BABIES IN SPACE?

It's one important piece of a larger puzzle of learning how to live and reproduce in space.

Within 15 years we expect a space-born baby. And a space-conceived baby will definitely happen even quicker, in around five years, because that's much easier and it has fewer ethical implications.

The upcoming space tourism sector is expected to become a magnet for crazy rich people, and also for nations in this new space race to grab the unique achievement of having the first naturally conceived baby in space, and baby born in space. And that would be unethical in many ways, and medically, there would be many risks that we'd have to prevent. So before that we have to tackle this [ethical] problem. We have to do that research.

It could also increase awareness for the importance of space exploration, and contribute to the ambition of NASA and the big space agencies to have permanent human settlements on other planets, the Moon, Mars, etc. That's pretty pointless without learning how to reproduce in space.

The big space agencies cannot address this question because they are funded by taxpayer's money and it's ethically delicate. So they explicitly want the focused companies to address these issues. And that's why we are doing this.

And your question is, of course, about the most sensational ambition that we have. But we have to work step by step. Our focus is on bringing IVF technology to space as a first step.

IS THE END GOAL IS TO LEARN HOW TO SUCCESSFULLY REPRODUCE IN SPACE?

Yes. To learn about all the different stages, and even in different areas of space. On Earth, we're protected by the planet's magnetosphere, and on the Moon there is a lot less protection, and on Mars it is non-existent.

BY THE TIME YOU'RE READY TO FLY PREGNANT WOMEN INTO SPACE TO GIVE BIRTH, IT WOULD BE BEYOND EXPERIMENTING, RIGHT? IT WOULD BE SAFE?

Exactly. Experimenting suggests relatively high failure risk. And that is not an option for something delicate like this. That would never be accepted by any ethical conditions for good reason. We need to ensure that the total risk involved in this mission will be less or similar to childbirth on Earth. The experts we work with are convinced that we can do that in 10 to 15 years.

WHEN AND HOW WILL YOU SELECT PEOPLE TO GIVE BIRTH IN SPACE?

We have extremely elaborate set of selection criteria to make this as safe as possible; age is one of the criteria. But we haven't started recruiting yet as we do not have a clear time window.

GETTY IMAGES

"We need to ensure that the total risk involved in this mission will be less or similar to childbirth on Earth"

If we knew that it was going to happen in two years, then we could start this recruitment. If, say, Jeff Bezos [founder of aerospace company Blue Origin] said, "This is an urgent priority, here's a billion dollars," then we can do a lot of parallel research, and then we might be able to do this within a few years and in an ethically acceptable way.

But that will probably not be the case. So, it might take 12 years or 15 years. And as long as that time window is so open, it's useless to give people false hope. So our focus is on the first steps to IVF in space, which will already take some four to five years. And then we move up further steps and as soon as we're ready for that step [giving birth in space], and we know more about all the details, only then we can start recruiting. It's encouraging to have people who want to sign up.

SO YOU ALREADY HAVE WOMEN WHO ARE INTERESTED IN DOING THIS?

We are having discussions with people who would be interested to participate. We want to learn as much as possible about their perception of risks, but also their needs, in a psychological way, so we can address those issues.

We didn't have to find them. They found us. They just sent us emails and they say, "We're interested. Can you give us more information?" We explained that we're not recruiting because it's not our focus yet. We understand that the media is especially interested in this, and that's fine and we should reach a lot of people with that as well. But it's not a timed plan.

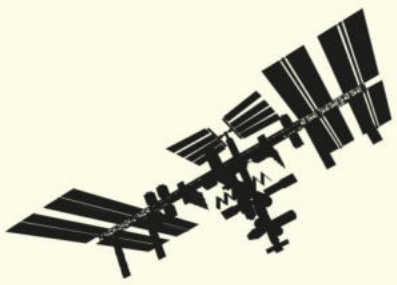
HOW DO YOU STUDY REPRODUCTION IN SPACE WITHOUT ACTUALLY SENDING PEOPLE UP THERE?

There is so much knowledge and expertise already based on animal models, but also on the basis of knowledge about human physiology on Earth. Part of our research is in designing missions and following developments such as the space tourism sector and the spacecraft that have a low gravity profile. A lot of information is just open and it's about combining all those insights. You don't need to have a physical lab for those mission designs, you just have to talk to people who have been dealing with all of those domains.

Of course, our research will imply studying cell samples inside our research platform. If we are re-engineering IVF technology then we have to build a prototype and test it and validate it with animal cell samples and eventually with human cell samples, but for that we need additional funding and we're working on that.

We work with a growing group of some 80-plus international experts in biomedical space technology, ethical issues, legal issues, space law issues. We are not fixed to our hometown in the Netherlands. I visit the US, Germany and the UK. Experts are from all over the world. We are hoping to collaborate with Asgardia, the first space nation, as our ambitions overlap.

DR EGBERT EDELBROEK
Egbert is chief innovation and strategy officer at Spaceborn United ***(spacelifeorigin.nl)****.*
Interviewed by science writer Mićo Tatalović.



International Space Station

SPACE

NASA celebrates historic month

On 19 October, NASA astronauts Christina Koch and Jessica Meir made history by completing the first all-female spacewalk. Meanwhile, on Earth, NASA engineers unveiled their latest prototype for the spacesuit that will be worn by the first woman to walk on the Moon

1. Kristine Davis, a spacesuit engineer at NASA's Johnson Space Center, shows off a prototype of the snappily-named Exploration Extravehicular Mobility Unit (xEMU) at the NASA headquarters in Washington. The xEMU suit will be worn by the first woman and next man to walk on the Moon as part of the Artemis programme, which is scheduled for 2024. Compared to previous suits, the xEMU is more flexible, allowing greater movement.

2. Jessica Meir (left) and Christina Koch (right) inside the Quest airlock preparing for their first spacewalk together, and the first all-female spacewalk. They are holding the pistol grip tools they will use to swap out a failed power controller unit. The unit regulates the charge to the batteries that collect solar power and distribute it to the International Space Station's systems. The duo spent a total of seven hours and 17 minutes carrying out the repair work.

3. This shot shows Meir readying herself to exit the Quest airlock and venture out into space. This spacewalk was Meir's first and Koch's fourth.

4. Meir appears relaxed as she waves and smiles at the camera while carrying out the repairs.

5. Koch took a space selfie showing the Earth behind her as she ventured out of the ISS to replace the failed power unit.

1

2

NASA X4, NASA/JOEL KOWSKY


3


4


5

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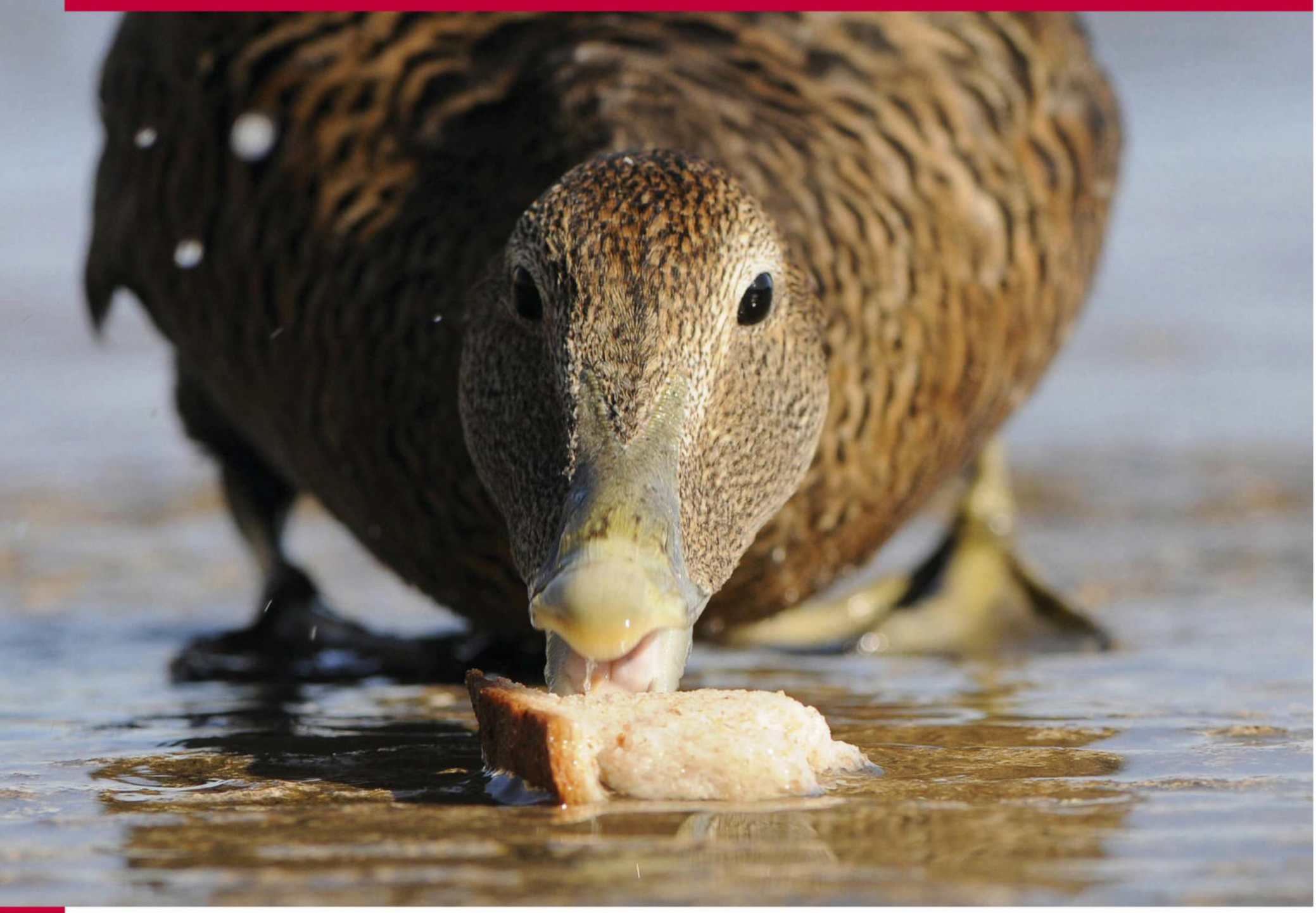

ANALYSIS

FEEDING WILDLIFE: CAN IT DO MORE HARM THAN GOOD?

In October, a handmade sign went viral. It claimed that ducks were starving because people were no longer giving them bread, due to concerns that it could make them ill. But is feeding ducks and other birds a harmless pastime, or should we leave them to fend for themselves?

"Just like us, birds need a varied diet to stay healthy"

BBC *Visit the BBC's* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

WHY ARE PEOPLE WORRIED ABOUT FEEDING BIRDS?

Throwing handfuls of bread to ducks is a childhood rite of passage that many, myself included, have long seen as harmless enough. But in recent years, some scientists have suggested that bread might not do birds' digestive systems any good. Organisations such as the UK's Canal and River Trust have also recently discouraged it. They say that as uneaten food decays, the water quality deteriorates and algal blooms can occur. Plus, by encouraging ducks to congregate in one place, the build-up of droppings and outbreaks of disease such as botulism may become a problem too. Meanwhile, many cities have signs telling us not to feed pigeons and gulls, which are deemed a 'nuisance' due to the mess they make, and because scattering bread inevitably attracts rats and mice.

It seems that the public has heeded these warnings, and that fewer of us now feed birds this way. In October, a homemade sign went up in a Derbyshire park claiming that the local mallards and other quackers were dying of starvation, and imploring visitors to carry on feeding them as before. When online posts about the notice went viral, feathers flew as ornithologists and conservationists debated the merits of doling out bread to wildfowl. So who is right?

HOW DOES BREAD AFFECT BIRDS?

Paul Stancliffe of the British Trust for Ornithology (BTO) points out that there's scant scientific evidence for bread harming birds, adding that, as little research has been done, it could even turn out to be beneficial. "We just don't know," he says. So although bread is a heavily processed 'unnatural' foodstuff intended for humans, that alone may be insufficient grounds for not feeding it to birds.

In the 1980s, the Wildfowl & Wetlands Trust (WWT) carried out a comparative study of different flocks of mute swans, and the birds that guzzled the most bread had weaker muscles, implying that a bread-heavy diet might be the cause. "Our official line is that bread is okay for ducks, geese and swans, but only in moderation," says WWT's Peter Morris. "However, this advice comes with several other caveats." The first is that it's best offered in winter, when there is less plant and insect food around. In spring and summer, too much artificial food may not be a good idea, since young wildfowl have to learn how to fend for themselves and natural food will contain a wider range of nutrients to help them grow.

LEFT This handmade sign appeared in a park in Derbyshire, sparking a viral debate about whether it was okay to feed bread to ducks

"Just like us, birds need a varied diet to stay healthy," says a spokesperson for the Royal Society for the Protection of Birds (RSPB). "Although ducks, geese and swans can digest all types of bread, too much can leave them feeling full without giving them all of the important vitamins, minerals and nutrients they need."

When bird feeding first became popular in the UK in the 19th Century, some Victorians preached tough love, arguing that such handouts would only make our feathered friends lazy and dependent on welfare. Such moralising sounds old-fashioned nowadays, but may have a grain of truth. Morris says that there is a theory that wildfowl can get 'hooked' on easy meals, losing interest in other types of food. Another danger, he says, is that birds fed regularly end up tame and habituated to humans, placing themselves at greater risk of predation.

GETTY IMAGES X2

IS THERE A WAY TO SAFELY FEED THEM?

Both the RSPB and WWT point out that, even if everyone feeds bread in only small amounts, that still adds up to quite a lot. We have no way of knowing what else a duck, goose or swan at the local park has been eating. So what can we safely give these birds instead? "We encourage people to use things like sweetcorn, porridge oats, crumbled biscuits and defrosted frozen peas, as well as bird seed," the RSPB spokesperson says. The WWT agrees, and additionally recommends chopped green vegetables.

WHAT ABOUT THE BIRDS IN MY GARDEN?

One thing is certain: feeding birds is now big business, with UK consumers spending between £150m and £200m a year on bird food. The vast majority goes on seeds, peanuts and fat balls for garden birdfeeders, rather than birdseed for ducks and other wildfowl. "We are a nation of gardeners who have become a nation of garden-bird lovers," wrote naturalist Stephen Moss in his 2011 book *Birds Britannia*. This national obsession has had a dramatic effect on bird numbers, boosting those of species such as the goldfinch and long-tailed tit. It has even influenced evolution itself. Some populations of an insectivorous warbler called the blackcap have started to visit gardens in southern Britain in winter, attracted by the food on offer. They have even begun evolving a longer, narrower bill better suited to feeding on sunflower seeds.

Whether in a garden or park, feeding birds is for many of us our first memory of interacting with nature in the wild. As the RSPB says: "This experience can be an important step towards understanding our natural world and appreciating that we all play a role in caring for it. And, as we all become more concerned about becoming increasingly disconnected with our natural world, it is important we encourage people to feed the birds and enjoy the wildlife around them."

by **BEN HOARE**
(@benhoare5)
Ben is a science and nature journalist, and the features editor of BBC Wildlife *magazine. His latest book,* The Wonders Of Nature *(£20, DK Children), is out now.*

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REVIEW

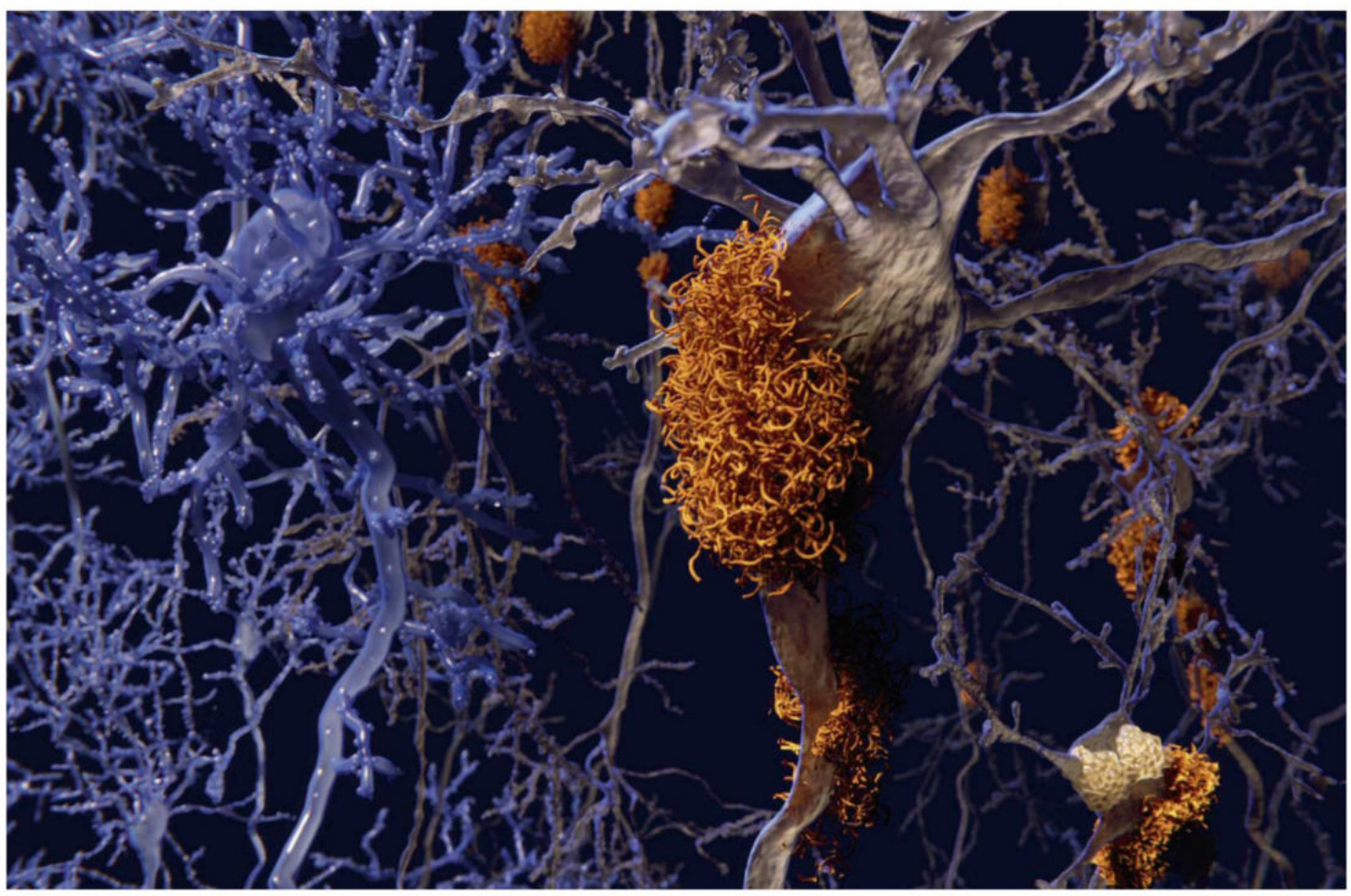
HEADING AND DEMENTIA: ARE FOOTBALLERS PUTTING THEMSELVES AT RISK?

A new study has revealed that footballers are more likely to die of degenerative brain disease than non-players. Former pro footballers have called for a ban on heading, and the Scottish Football Association announced last month they were considering a ban for children under 12. But what does the research say?

Back in 1970, Jeff Astle played for England at the FIFA World Cup. In 2002, after suffering with a dementia-type brain disease for a number of years, he died at his daughter's home, aged just 59.

LEFT Goalkeepers are less likely than outfielders to be prescribed dementia drugs in later life

BELOW Characteristic protein 'plaques', visualised here in orange, can be seen in an Alzheimer's brain



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Later analysis in 2014 of Astle's brain revealed he'd suffered from chronic traumatic encephalopathy (CTE), a brain disease often seen in boxers. The neurosurgeon who performed the examination, Dr Willie Stewart, concluded that much like powerful blows to boxers' heads, Astle's repeated heading of the ball had caused his CTE.

Now, Stewart has been part of a team that has revealed that former professional footballers are five times more likely to have a dementia-type illness, and three and a half times more likely to die from it than members of the general public.

Since the findings were published in October, former players and football fans have called for a change in the rules around head injuries and heading the ball. At time of writing, the Scottish Football Association is considering a ban on children under 12 heading the ball. But does the science support this?

Stewart's study looked at data from over 7,000 former professional players and 23,000 controls from the general population, matched on the basis of sex, age, and socioeconomic class. The findings were based on mortality rates and prescriptions of drugs for dementia symptoms. "Out of those 1,180 footballers in our study who died, 222 had died of

"We don't know how many concussions or head impacts a player had. It's just not documented"

neurodegenerative disease-related cause. Two hundred and twenty-eight members out of the control group [of 23,000 people] died of a neurodegenerative disease," explains Stewart. "Considering there had been three times as many people in the control group, we expected to see three times the number of deaths."

The study set out to determine whether professional footballers are at greater risk of getting and dying from dementia. But within this, there's another factor at play: was heading the ball or collisions between players to blame?

"That's very difficult to determine with the data we had," says Stewart. "We don't know how many concussions or head impacts a player had. It's just not documented."

To attempt to tease out a conclusion from the data, the team compared outfield players to ➤

goalkeepers. "Although we saw a slightly lower mortality in goalkeepers than in outfield players, statistically we just couldn't prove it wasn't chance," says Stewart. "But when we looked at prescriptions, goalkeepers were less than half as likely to have been prescribed a dementia drug, which would imply that goalkeepers' rates of dementia were about half that of outfield players."

Currently, the research that's looked at the pathology of dementia in footballers and other sports suggests to Stewart that exposure to head injury is the most likely risk factor. There have been suggestions that the heightened numbers could be related to the amount of drugs or alcohol that professional players have been exposed to.

"These arguments don't stack up," argues Stewart. "We're talking about something that is a common agent to boxers, American footballers, rugby players, footballers, wrestlers, victims of domestic violence, road traffic accidents… there isn't one common risk factor that you can draw through all of these other than head injury."

"In rugby, for instance, if there is a suspected head injury the player goes off and is assessed for up to 10 minutes at the side of the park. That doesn't happen in football"

THE BRAIN AFTER HEADING

So how exactly does head impact and concussion lead to dementia? Dr Magdalena Ietswaart, senior lecturer in psychology at the University of Stirling, has spent the last few years finding out.

In 2016, Ietswaart and her team discovered that there are detectable changes in the brain after heading the ball just 20 times.

"We know that there is a link between traumatic brain damage, such as concussion, and long-term damage," says Ietswaart.

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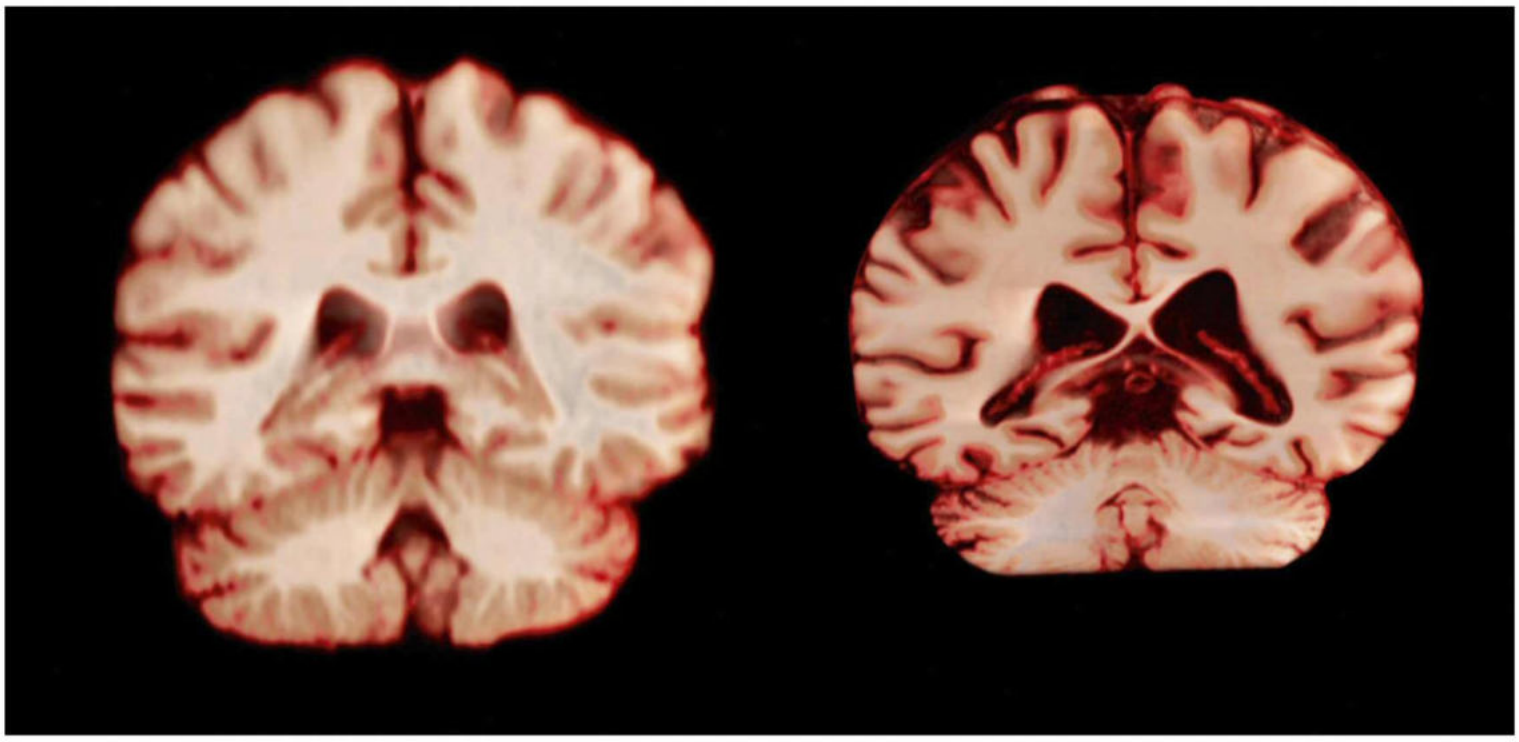


LEFT Just 20 headers over the course of a football practice had a temporary impact on the brain

ABOVE Healthy brain (left) compared to a brain with Alzheimer's. The Alzheimer's brain is smaller, due to the degeneration of nerve cells

To measure how brain chemistry is affected by heading, Ietswaart and her team looked at how long it took for a signal to travel from the brain to, say, a muscle in the leg. The team found that the communication between the brain and muscle slowed after just one session of practice headers.

"We also found effects on memory after heading the ball, which is interesting," says Ietswaart. Scientists know that a healthy brain chemistry is needed for processes of plasticity (the ability of the brain to change and adapt), which is essential for things like learning and memory.

The participants' inhibited brain-to-muscle communication levels returned to normal after 24 hours, but Ietswaart warns that the long-term consequences remain unknown.

The study faced criticism from some quarters. "People have said to me that footballers head the ball [during a game] much less now, but there is no science to say that less heading is then going to be fine." says Ietswaart. "Similarly, people said that it was 'extreme' that we had people heading the ball 20 times. But that was the number of times that local football players would practice heading the ball during training. And there's nothing to say that if you just head the ball 10 times, everything is fine."

One concern that both Ietswaart and Stewart share is when people blame the old, leather-style footballs of bygone days, they'll think the new plastic ball is safer. In fact, Ietswaart's 2016 study was done with the modern ball.

"We certainly have no evidence whatsoever to say that anything that has happened in the game in the last 10 years, 20 years, or longer, will have changed the risk of neurodegenerative disease for footballers," says Stewart. "My concern would be that if we assume – with no evidence or data to back that up – that technology in the modern game has changed and that there's no risk any more, we may be putting our footballers at risk of carrying on with a high chance of getting the disease."

According to Stewart, there needs to be better management of head injuries in the modern game. "In that regard, football is woefully inadequate. If you look at rugby, for instance, if there is a suspected head injury the player goes off and is assessed for up to 10 minutes at the side of the park. That doesn't happen in football. There might be a passing few minutes allowed on-field for an assessment, but it's nothing like adequate. It's the same injury. But it's being managed in quite different ways."

BAN OR NO BAN?

With regards to a ban, both researchers are reluctant to call it a decision informed by science. "The truth is we don't know whether a developing brain is more at risk," says Ietswaart. "We do now know that the brain is still under construction until the age of 23. Particularly between the ages of 14 and 23, the frontal lobes in the brain get a complete rewiring. Nobody wants to know that a player in their prime still has a developing brain."

"We've been doing some work looking across youth groups, and it turns out that younger kids – under 14s – barely, if ever, head the ball during a match," comments Stewart. "Are we training kids during the week by repetitively hitting the ball off the head, for that one rare occasion where they might head the ball during a match? I don't think they're losing anything from the game to say children will not head the ball any more. But going further than that into adults and professionals… we'll need to get some science and take that forward before making decisions on heading."

by AMY BARRETT
Amy is the editorial assistant at BBC Science Focus.

COMMENT

ECO-ANXIETY: HOW DOES THE HUMAN MIND DEAL WITH EXISTENTIAL THREATS?

From plastic pollution to climate change, there's a lot of environmental news that can cause existential angst. Is it possible to think helpfully about these issues or are they too big for our minds to cope with?

Faced with a big problem, it's normal to try to think our way out of it. While sometimes problem-solving can be helpful, it can tip into repetitive worrying over things that we can't solve in our own heads. A similarly repetitive thinking style, but one focused on the past, is ruminating – chewing over and over things that have already happened. This can be problematic, as it's a thinking style linked with depression. Another way of coping with existential threats is to avoid thinking about them altogether because they feel so massive. But this can mean that they seem even more overwhelming when we do eventually think about them.

Brain scan studies suggest there is a particular brain region involved in the processing of existential threats: the anterior cingulate cortex (ACC). This area is also involved in our behavioural inhibition system (BIS) – a system that encourages us to stop doing, and pay attention to something. Researchers have suggested this brain area is related to common behavioural reactions to existential threats: that feeling of being paralysed to act in the face of something looming, and the tendency to consume a lot of information about the threat without changing our behaviour.

ECO-ANXIETY

'Eco-anxiety' is a term that's been used by the American Psychological Association (APA) in a report about the effects of climate change on mental health, but it's not an official diagnosis. Psychologically speaking, anxiety about anything arises from how we perceive a threat, and so 'eco-anxiety' makes sense, even though the threat it relates to is real. Since it's not a specific mental health problem, eco-anxiety can't be 'treated' as such. However, if worries about climate change are creating significant distress, there are things that can help. Often it's a case of doing the opposite of what our anxious state of mind might be encouraging us to do, instead of letting our worry thoughts paralyse us. For example:

"'Eco-anxiety' is a term that's been used in a report about the effects of climate change on mental health"

ALAMY

- **Working out what things we can control and taking step-by-step action on those things can increase our sense of agency. For example, thinking about our recycling habits, energy consumption, travel and diet to minimise our environmental impact.**
- **Balancing worst-case scenario news with other information and activities, like spending time in nature and with others.**
- **Staying connected with people we love and caring communities, so we feel less alone with our worries.**
- **Paying attention to the effects of how we are thinking about the problem so we can change this if it's unhelpful.**

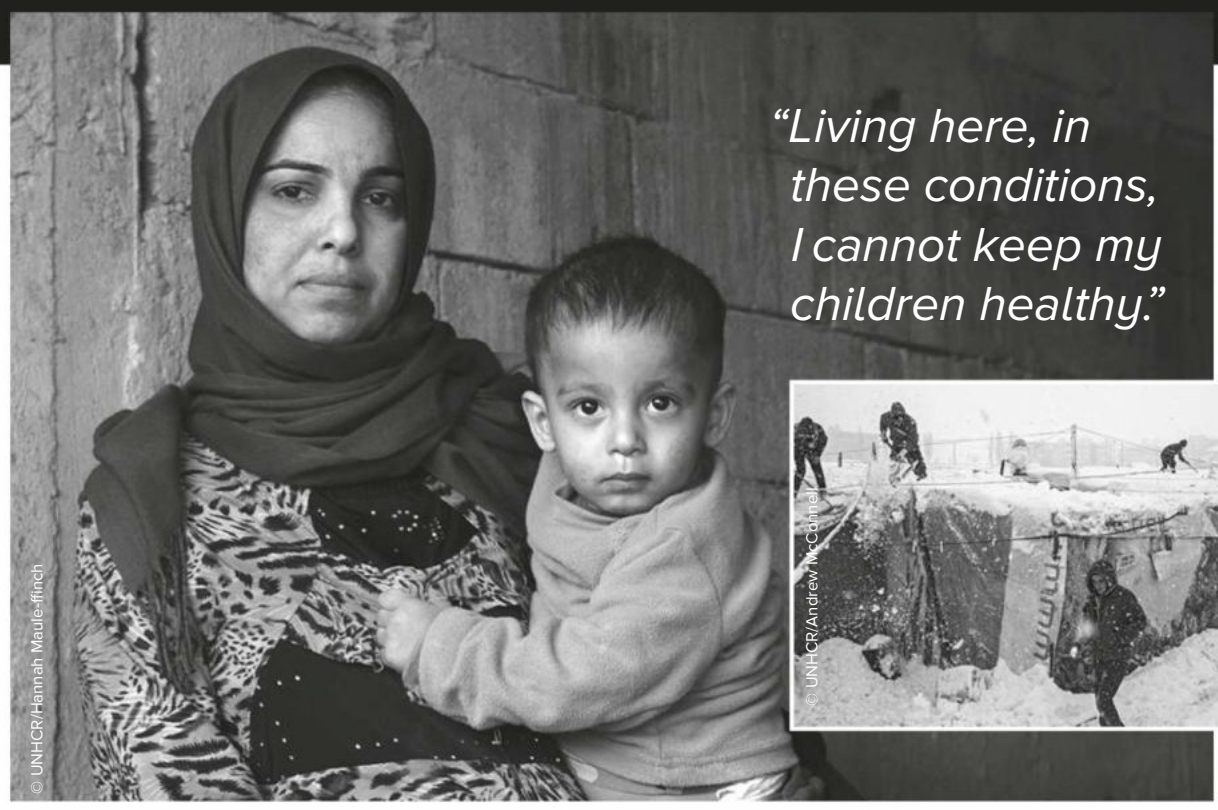
When we're really scared about something, it's common for our sleep, diet and exercise to suffer. Making sure we're eating healthily, and that we have a regular sleep and exercise routine, can make a difference to how overwhelmed we feel. Though this might feel selfish, we won't be able to do much about climate change if we don't take care of ourselves.

It's important to recognise if anxious or depressed thoughts, feelings and behaviours have become an overly large feature of your life. There are evidence-based treatments for anxiety and depression if you think you might be experiencing them, and it's worth reaching out to seek help. There is also information on how you can reduce your environmental impact, which may help you to feel less helpless. **SF**

by **DR LUCY MADDOX**
Lucy is a consultant clinical psychologist and writer.

URGENT APPEAL: help Syrian refugee parents like Khitam to protect their children through the winter.

UNHCR The UN Refugee Agency



Khitam lives with her four young children, husband Abdelsalam, and his elderly parents in a single, damp room of a half-built apartment block near Tripoli, Lebanon.

There are holes in the walls and ceiling, and they share a toilet with other refugee families crammed into the building. Khitam and Abdelsalam are mentally and physically exhausted after years of struggling to survive, unable to earn a living and fighting a daily, relentless battle to feed their children.

Right now, they are terrified by the prospect of another winter in their cold, uninsulated single room. Another winter where they will feel every blast of icy wind. Another winter where every time their children cough or sneeze they will fear they have contracted a lethal respiratory condition like pneumonia or tuberculosis.

100kph
WIND SPEEDS RECORDED DURING STORM NORMA IN LEBANON, JANUARY 2019

UNHCR, the UN Refugee Agency, needs your support to help parents protect their children this winter.

Please will you give £75 to provide a refugee family like Khitam's with a winter survival kit to protect against the freezing weather?

The kit contains essentials such as a heating stove, thermal blankets and a tarpaulin for insulation. It could mean survival for a family like Khitam's.

Two winters ago, as a result of their exposed and unsanitary living conditions, Khitam and all four of her children became ill. Baby Bilal had a high temperature and diarrhoea. Her sons Khaled (3, pictured) and Abdul Rahman (8) had chest infections and their sister Fatimah (4) contracted worms. Khitam herself developed painful growths on her throat and lost her voice. Without access to a free healthcare system like we have in the UK, Khitam became overwhelmed with worry about how to pay for the treatment and medicines her children needed.

£75
could provide a Syrian refugee family with a winter survival kit

"I felt helpless. My children were coughing and crying and there was nothing I could do."

Khitam believes that without assistance from UNHCR "my children would be dead".

Across Lebanon and Jordan, seven of the last eight winters have brought heavy snowfall and temperatures regularly drop below 0°C.

1.7 million Syrian refugees are living, like Khitam's family, in unfinished or derelict buildings, or in makeshift shelters, sometimes made of little more than wood and plastic sheeting.

This coming winter, when temperatures are likely to fall below zero, the lives of the most vulnerable: young children, pregnant women and the elderly, are at grave risk from hypothermia, frostbite and diseases like pneumonia.

With a gift of £75 you can provide a winter survival kit containing a stove, blankets, winter clothes and a tarpaulin to help a family insulate and heat their home.
Please give today – you could save the lives of children like Khitam's.

Give at **unhcr.org/wintersupport**
or call **0800 029 3883**

With £75, you can give a winter survival kit containing:

STOVE
For heating and cooking. An absolute essential.

TARPAULIN
For insulation. Keeps the cold out and the warmth in.

BLANKET
Families left their homes with nothing. A simple blanket could save a life.

WINTER CLOTHES
Hats, gloves and scarves keep families warm, indoors and out.

Yes, I will help Syrian refugee families survive the winter

UNHCR The UN Refugee Agency

Please accept my gift of: ☐ £75 ☐ £150 ☐ £225 **My own choice of** £

Please post urgently to: **Freepost UNHCR**. You do not need a stamp. BFPAWI19B

Please debit my: ☐ Visa ☐ MasterCard ☐ Maestro

Card no. Maestro only

Valid from Expiry date Issue no. Maestro only

Signature Date / /

☐ I enclose a cheque or postal order made payable to UNHCR (Currently CAF cheques cannot be accepted)

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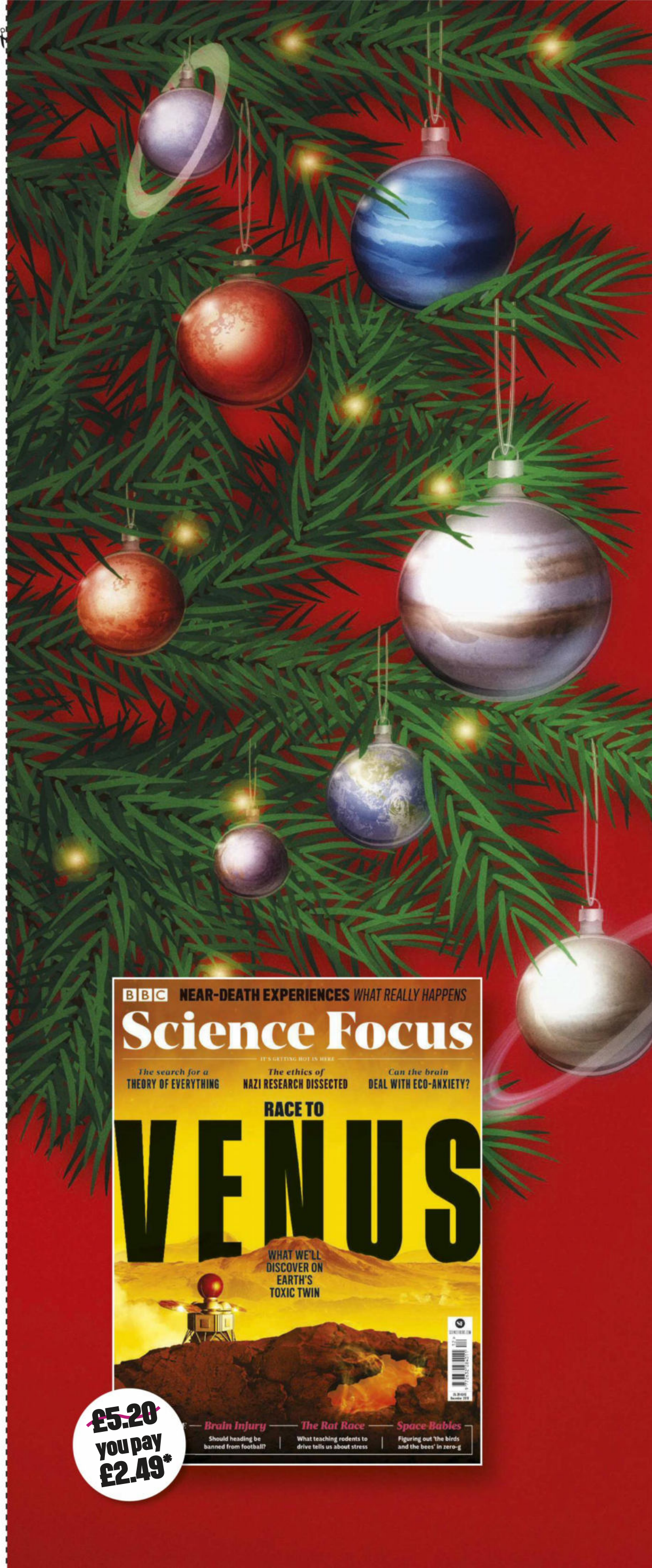

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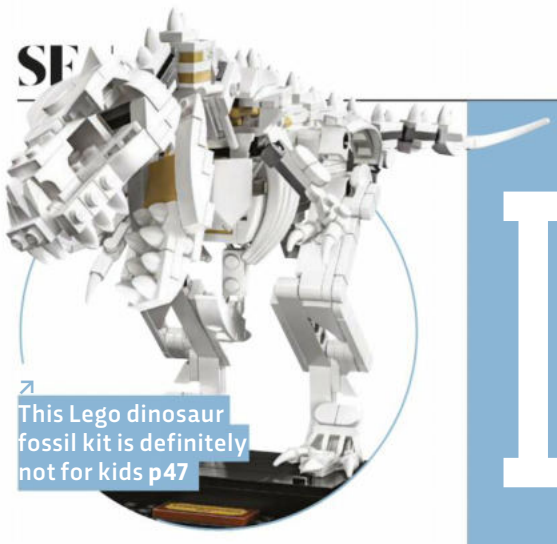


This Lego dinosaur fossil kit is definitely not for kids **p47**

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

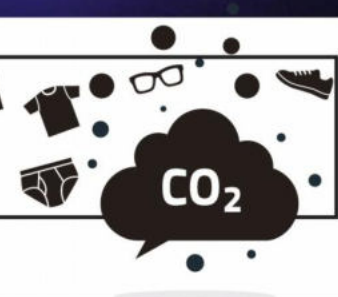
The new version of the Toyota Mirai was launched in October, and a production model will be available to buy in 2020

SPIDEY SENSES

Some jumping spiders can leap more than 50 times their body length. Engineers want to mimic this ability to create better robot vision **p45**

DIRTY CLOTHES

The global footwear and apparel industry produces more CO_2 in a year than the airline and shipping industry combined, according to a report by Quantis



Riversimple Rasa

The company building this sleek hydrogen-powered two-seater car has a £1.5m grant to build a fleet for a 'clean mobility trial' in Monmouthshire.

Energy Observer

This hydrogen boat has sailed around the world, and will keep touring to fine tune fuel-cell tech in the hope that it could one day help clean up shipping.

Arcola Energy

Next year, Arcola Energy is sending 25 of its hydrogen buses to Liverpool as a trial. If successful, it hopes to test rubbish trucks next.

FIRST LOOK

Toyota's new hydrogen car

The next-gen Mirai aims to secure its place in a fossil-fuel-free future

We like the idea of hydrogen cars. You go to a fuel station, fill your tank, and drive off a few minutes later leaving nothing but steam in your wake. So, when the Mirai first went on sale in 2015, we hoped we might see more like it on the roads, with hydrogen fuelling stations following close behind.

Sadly, that hasn't been the case. But with Tokyo 2020 about to turn the spotlight back on hydrogen cars with its hydrogen-powered Olympic Village, Toyota invited us to give its Mirai another chance. We drove the Mirai from London to Swindon on the eve of the release of the new model. For a car that pumps steam out the back, it's reassuringly unremarkable to drive. In the same vein, filling up the Mirai was a totally familiar experience (aside from the futuristic nozzle that pumps the gas into your tank). It costs about £60 to fill the tank, which should get you a range of 500 kilometres (300 miles), so it's only marginally more expensive to fill than a petrol or diesel car. Of course, it's inside the car where things get more interesting. To power the motors, a fuel cell strips electrons from the hydrogen. These free electrons flow around the circuit as a current, and the hydrogen ions that remain react with oxygen ions to produce water so pure that it can be drunk from the Mirai's exhaust (although we wouldn't recommend it!).

"THE GAWKY, ANGULAR DESIGN HAS BEEN REPLACED BY SOMETHING MORE ELEGANT"

As impressive as the car is, there's still a way to go before hydrogen cars will be ubiquitous. Currently, there are only a handful of hydrogen refuelling stations around the UK, mostly clustered in London. More of the country will be serviced in the coming years: there are plans for a total of 19 to be built by 2020, and 65 by 2025.

It's a 'chicken and egg' situation. If there are no filling stations, then there's no market for the cars, and if there are no cars in the area, there's no market for filling stations. But that doesn't mean we're done with hydrogen yet.

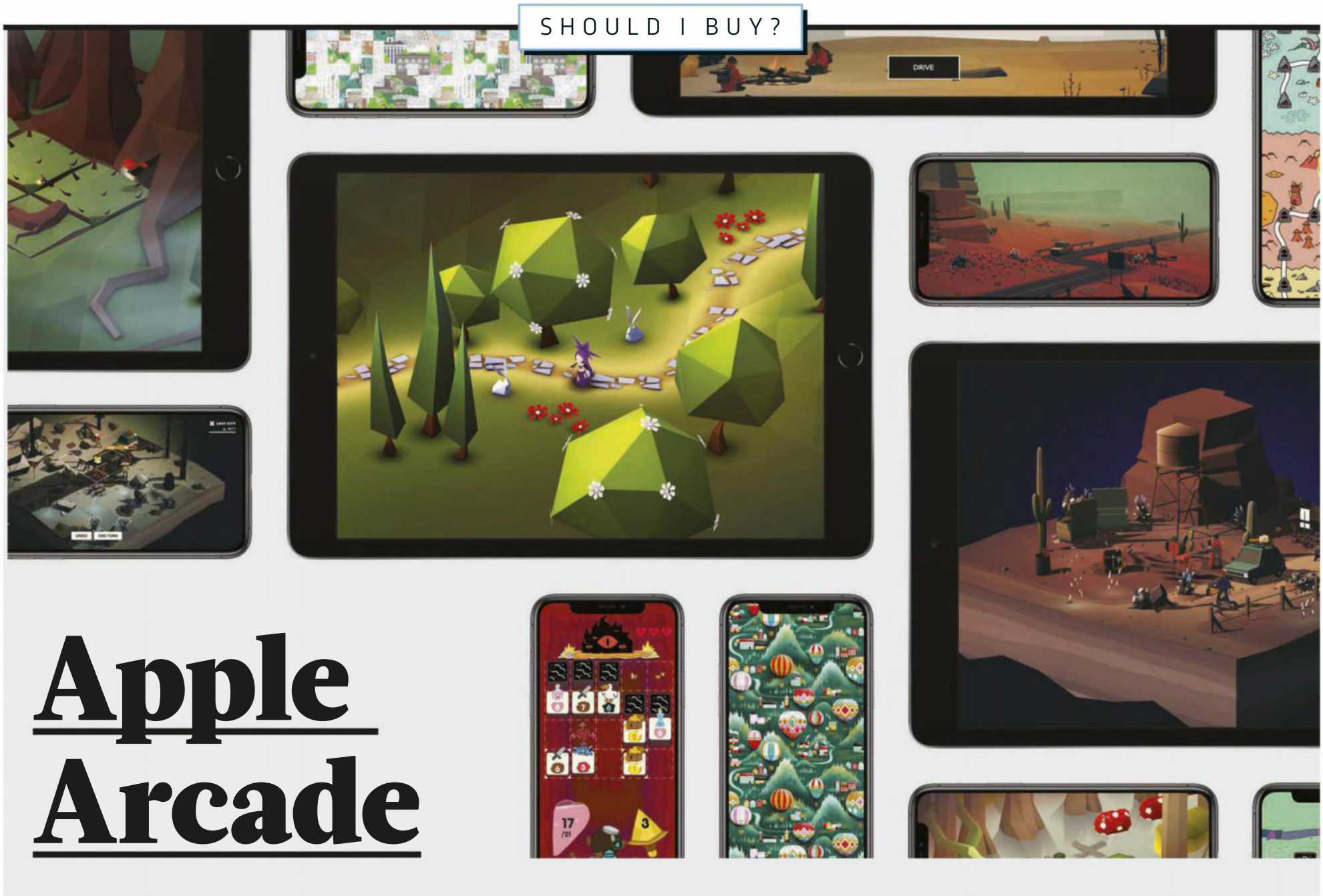
Toyota hopes to give the car mass appeal with its new version of the Mirai. The gawky, angular design has been replaced with something sleeker and more elegant, while the interior has been given a luxury finish to match. The idea is to make hydrogen cars desirable, rather than a green oddity.

Hydrogen fuel cells outstrip petrol power for long journeys and heavy vehicles, though they're less efficient for city driving conditions involving short trips and small vehicles, making them perfect for lorries, trains and buses. This is why a hydrogen filling station planned for Birmingham won't be on a petrol forecourt but in a bus depot. Birmingham City Council has approved a trial of 20 hydrogen-powered buses in the city, providing a captive market for the hydrogen pump, and locals will be able to fill their own cars at a fuelling point on the same site.

With a more desirable hydrogen car on the market, and the 'hydrogen' Olympics on the horizon, who knows what's next?

The older model of the Toyota Mirai, as tested by the *Science Focus* team

SHOULD I BUY?



Apple Arcade

What is it?

A new(ish) way to pay for games. These days you can get a subscription for anything: beer, socks and, believe it or not, pasta. While we're not sure we're ready to start a monthly commitment to tagliatelle, Apple Arcade seems like a reasonable way to buy games. For £5 a month, you and five 'family members' can download as many games as you like from a curated selection of new titles across iPhone, iPad and Macbook.

Are there any other games subscription services?

If you've got a PS4, PlayStation Now offers access to a huge back catalogue of games for £8.99. There's also the imminent Google Stadia, which will cost £119 for a console, and then £8.99 for a 'pro' account. A range of subscription services are aimed at PC gamers, and even cloud services for people who want to play games without forking out on a gaming rig.

What games do I get?

We've had Apple Arcade for a month now, and the onus is on quality mobile games. Of late, app stores seem to be littered with free games that are little more than glorified slot machines, hoping to goad money out of you. Apple Arcade offers up refreshingly original games alongside new takes on classic formulas. It's aimed that those of us who like to snatch a few spare minutes to play, and is also perfect for parents who want to let their kids game without wondering where they left their credit card. In the store there are familiar faces in the shape of *Rayman*, *Sonic* and *Pac-Man*, next to newcomers. From puzzlers to arcade games to sports, there's legitimately a title for everyone.

Is it worth it?

Absolutely. For the price of a London pint, six people get access to over 100 games across their devices – as long as they belong to the church of Apple. As the end of our free trial nears, we're struggling to find a reason to quit. Right now, we're loving the absurdist, Dada-esque *What The Golf*. It's a physics-based parody where you launch buildings into the sky, wrestle with cats and fire horses over trains. If we get bored, we can cancel the subscription at any time.

Are the games any good?

What The Golf and the brilliantly bizarre *Cricket Through The Ages* would be worth £5 on their own. But we're also about to sink into the dazzling *Sayonara Wild Hearts*, a novel rhythmic game which is like playing through a psychedelic pop video. When we want something more 'traditional', we're going to try *Oceanhorn 2*, an adventure game for anyone who's a fan of the *Zelda* series.

What's the catch?

Well, there's nothing surprising. You have to own an Apple device, and some games will struggle on older devices. But if that's a problem, you can cancel your trial before payments start, or indeed, at any time. Best of all there are no aggravating ads, or sneaky microtransactions. Apple Arcade may not appeal to some gamers – there's no wars to reenact or demons to slaughter – but it does offer up a bunch of playful titles that won't fail to put a smile on your face.

APPLE, ALAMY, LETSGODIGITAL

Jumping spiders are inspiring robot vision

The eyes have it

Scientists build cameras for tiny robots based on spider vision

If we want to build robots that can interact with the real world, they have to be able to take the 2D images recorded by cameras and turn them into 3D maps. The tech to do this exists – facial recognition in smartphones relies on depth perception to chart your features – but engineers want to make it smaller and more efficient for use in microrobotics, augmented reality and wearables tech.

Of course, evolution has already has a solution: the eyes and brain of the tiny, but formidable jumping spider. A team at Harvard University studied the arachnids to understand how, with their relatively small brains, they manage to accurately and rapidly pounce on unsuspecting flies

Each principal eye of a jumping spider hosts not one, but several retinas arranged in layers. Each has its own focal length, so a fly in the spider's vision will appear sharper in one retina, but blurrier in the others. This information is sent to the brain, where a quick calculation about the difference in acuity between the images is made, and this tells the spider how far away the fly is. The Harvard researchers have replicated this system with a 'metalens'. This new material can produce multiple images with several focal points from just one surface. "The metalens splits the light and forms two differently defocused images side-by-side," explains Zhujun Shi, who co-authored the paper. An algorithm then quickly interprets the differences and creates a depth map of the scene. In this way they're able to mimic the spider's efficiency and speed, and one day will fit the camera to small robots or smartphones.

"THE METALENS SPLITS THE LIGHT AND FORMS TWO DIFFERENTLY DEFOCUSED IMAGES SIDE-BY-SIDE"

TECH DIGEST

PLAYSTATION 5

It'll be here for Christmas 2020.
Last month, Sony finally shared some intel about its hotly awaited system. The tech company says that when the PS5 goes on sale it'll be the world's most powerful console.

It'll have a new controller.
Let's be honest, we're not expecting the design to stray far from the classic PlayStation configuration, but Sony seems particularly excited about the new haptic system that will use vibration to give players feedback. Interestingly, the shoulder buttons (L2 and R2) will be adaptive triggers. In other words, they'll feel harder or easier to push down depending on what was going on in the game.

New chips and tricks.
Of course there's a new bigger, brawnier processor inside, but for once better graphics might not mean longer loading times. A new solid-state drive will make reading and organising files more efficient, and therefore faster.

Everyone's excited about ray-tracing.
These days, in terms of graphics, being able to accurately simulate light and how it behaves is key to taking realistic visuals to the next level. PlayStation's hardware architect Mark Cerny has now confirmed that this tech will be built into the PS5's hardware, to the relief of superfans.

Ideas we like...

1.
Tile gets tinier

A Tile keyring connects to your phone's Bluetooth and, if you lose your keys, alerts you when you've moved out of range (about 30m). It'll also send the GPS location of the last time it had a connection to your phone. Now Tile's tech has been squeezed into a waterproof sticker little bigger than a £1 coin that will adhere to any flat surface, including phones or cameras. If you lose a device, you can 'activate the community' which will let you know if another Tile user's smartphone detects a stickered device nearby.

Tile Sticker, £34.99 for two, thetileapp.com

2.
Simplisafe in the UK

After years of success in the US, Simplisafe is now available in the UK. This smart security system caught our eye with its simplicity. The basic level package offers a front door entry sensor, a camera and control pad. Or you can design your own system around your needs. There are two subscription tiers, Pro or Pro Premium, which offer 24/7 monitoring of your system.

Simplisafe, from £249, simplisafe.co.uk

3.
An all-electric SUV

SUVs are the second-largest contributor to the increase in global CO_2 emissions since 2010. As there's no sign of sales of big cars slowing down, we need more vehicles like Nissan's Ariya concept. Even if you're not in the market for a big SUV, it's good news that we're about to see a lot more variation in the types of electric cars on sale, which will hopefully mean prices start falling too.

Nissan Ariya Concept, nissan.co.uk

6.
Better sweater

Fast fashion creates a huge carbon footprint, so it can't hurt to go for something that's durable and made from recycled materials. Patagonia's Better Sweaters are made from old polyester and bottles, apart from the zips. Meanwhile, its Black Hole bag range has been made from 10 million plastic bottles (so far).

Patagonia Better Sweater,
Various products available, eu.patagonia.com

7.
Attractive smart light bulbs

Hue is the smart light bulb system from Philips that lets you remotely control the intensity and colour of your lighting from your smartphone. These new bulbs mimic vintage Edison-style bulbs, but since they're LEDs they're energy efficient and don't get hot. You can control a lightbulb directly via Bluetooth, or pick up a starter kit for £59.99.

Philips Hue, £19.99 per bulb, meethue.com

8.
Interactive gigs

Elton John fans will be able to mix his music live during his next tour. The Peex RX device pulls sound from the on-stage audio desk and pumps it straight to the audience's smartphones via the app. Audience members can then modify which instruments they hear more or less of through their earphones. So you could customise your sound by bumping up the keys in *Bennie And The Jets* or turning up Elton's vocals in *Saturday Night's Alright For Fighting*.

Peex RX at Elton John concerts in 2020
Peex.live

4.
Lego dino fossils

Well, that's Boxing Day sorted. This 910-piece set contains a 20cm-tall *Tyrannosaurus rex*, a *Triceratops* and a pterosaur fossil. Lego says that it's for anyone who's 16+, so it's only right that you open it after the kids have gone to bed.

Lego Ideas Dinosaur Fossils,
£54.99, lego.com

5.
Electric bike converters

The Swytch ebike converter claims to turn any bike into an electric bike. The kit consists of a small battery pack that mounts onto a bike's handlebars, and a motorised wheel that replaces your bicycle's front wheel. Together, the system will give you an ebike with a 50km range, while the 250W hub motor will help make hills easier. After a successful crowd-funding campaign, the Swytch will arrive in stores in April, and is available online now.

Swytch ebike Converter,
From £618, swytchbike.com

IFEEL ICE

IN FORT WORTH, TEXAS, LOCKHEED MARTIN IS BUILDING ONE OF THE WORLD'S FIRST STEALTH JUMP JETS. WE VISITED THE FACTORY TO GET UNDER THE SKIN OF THIS NEW FIGHTER JET TECHNOLOGY

WORDS: ALISTAIR CHARLTON

ROLL CALL

The Lockheed Martin F-35 Lighting II is arguably the world's most advanced fighter jet. Built on a mile-long production line in Fort Worth and costing around £100m apiece, the plane is wrapped in a cutting-edge stealth skin to avoid detection by enemy radar, and uses augmented reality helmets to give pilots an unparalleled view.

Almost 30 years in the making, the F-35 is a trillion-dollar global effort with investment from Australia, Canada, Denmark, Italy, the Netherlands, Norway, Turkey, the UK and the US. The RAF and Royal Navy have ordered 138 jets to be used on the UK's two new Queen Elizabeth Class aircraft carriers. So far, 18 have been delivered, with plans for a further 30 by 2025.

I.E. NEED...

LOCKHEED MARTIN

LINE UP ↓

There are three variants of the F-35. The F-35A uses runways as normal, the F-35B is capable of short takeoffs and vertical landings, and the F-35C is designed for exclusive use on aircraft carriers, thanks to its foldable wings. Dozens of all three versions of the F-35 are in production at Lockheed Martin, their aluminium and titanium panels finished in a luminous green primer before their stealth skin is applied. The skin, a polymer-based composite designed to absorb electromagnetic wave energy, is known as radar-absorbing material, or RAM, and is highly classified.

In 2019, 131 F-35s are expected to roll off the production line, with that increasing to 140 in 2020, and on to a total annual output of 170 aircraft. The facility employs over 16,000 workers; engineers navigate the building by bicycle or electric golf cart, while the jets are manoeuvred on jigs from one workstation to the next. Each 1,900km/h (1,200mph) jet takes about 58,000 man-hours to build, then is flown to the country that bought it via several rounds of in-flight refuelling.

SILENT BUT DEADLY →

Key to the F-35's stealth is its smooth body. Instead of hanging weapons and fuel tanks from its wings and underbelly, the F-35's arsenal sits inside the craft. That way, its 'radar return' – how much enemy radar signal bounces off the aircraft – is almost zero. The plane's invisibility to radar is even preserved around the engine air intakes, which normally give planes away on a radar image. The F-35 is furnished with serpentine inlet ducts, which radar signals bounce back and forth around on their way to the engine. As a result, little, if any, of the signal finds its way back out again, reducing the aircraft's image on enemy radar screens. The 15.7m-long plane isn't invisible, of course, but to enemy pilots it might as well be. "If the enemy gets too close, it's their bad day," F-35 lead test pilot Alan Norman says.

But this near-invisibility can prevent conflict too. F-35 pilots can opt to avoid enemies and go about their business – a reconnaissance mission, perhaps – without being seen. "We don't have to fight if we don't want to. It's tremendous," Norman adds.

LOCKHEED MARTIN X2


FOD CONTROL
FOD CONTROL
FOD CONTROL
FOD CONTROL

FLIGHT SCHOOL ↑

Analogue dials are replaced by a 50cm by 20cm touchscreen, and pilots can adjust the layout to suit them. Instead of concentrating on each flight system and determining what that means for their control of the aircraft, F-35 pilots have more cognitive freedom to see the bigger picture and consider mission tactics. This tech-first approach appeals to younger pilots, or as Norman describes them: "Digital natives, people who grew up with iPhones ... the airplane helps us do our missions so well that a 10-hour pilot can be as good as a 1,000-hour pilot."

Norman adds: "Pilots become tacticians instead of technicians. Every jet becomes a battlespace commander because we have all this information."

Finally, the F-35's £325,000 pilot helmet is unlike any other. Airspeed, altitude and weapons targeting are projected on the inside of the visor, along with a 360° view captured by six external cameras then stitched together. "When the pilot looks down, their view is not obscured – they can see the terrain beneath the aircraft," says Norman.

by ALISTAIR CHARLTON
(@AlistairJ90)
Alistair is a freelance tech and motoring journalist.

SIXTH SENSE →

"There's no magic in this airplane," Norman says. "But what's closest is what we call sensor fusion ... it's a quantum leap in technology never seen before." Sensor fusion is what happens when an F-35 takes data from external sensors – like the heat signature of an aircraft several miles away – then interprets this, determines the threat level, and monitors the situation. If the potential threat level from that aircraft increases, the F-35 will let its pilot know and suggest they investigate.

The pilot can then look with their own jet, or view data from the sensors of other F-35s. That way, four F-35s flying miles apart can share their view and data, giving each pilot a complete view of the battlespace.

"F-35s do not hunt as individual airplane," says Steve Over, Lockheed Martin's director of business development. "They hunt as a pack, separated by vast distances in the airspace. If you're flying an F-35 there is never a situation where someone sneaks up behind you. You can take that out of the equation." SF

LOCKHEED MARTIN X2

The 12 days OF CHRISTMAS GIFT GUIDE

Looking for the perfect present for the gadget lover in your life? Check out these nifty cutting-edge tech gifts

1 JABRA ELITE 85H WIRELESS HEADPHONES

Give the gift of great sound with Jabra Elite 85h headphones – the best present you can give to someone who wants superior wireless calls and music anywhere and anytime thanks to SmartSound.

FIND OUT MORE AT JABRA.CO.UK/ELITE85H

2 ALPHA BY NITE WATCHES

You can always rely on the Alpha thanks to self-powered Tritium illumination technology, a ceramic bezel insert, sapphire crystal, 10-year battery life, 300m water resistance and Swiss Made movement. Only available from Nite Watches, £480.

FIND OUT MORE AT NITEWATCHES.COM

3 SEGA HOMESTAR FLUX

Gift a sky full of stars with a Sega Toys home planetarium. The Homestar Flux is the most powerful and advanced model, with a refined design, brilliant glass lenses and the brightest LED available.

FIND OUT MORE AT SEGATOYS.SPACE

4 THE NAKED SHAVE KIT

The perfect sustainable gift for men and women. Get a smooth shave and a clear conscience with this 100% plastic-free kit featuring double-edge safety razor with unique hourglass wooden handle, replacement blades and silky shaving soap.

FIND OUT MORE AT NAKEDNECESSITIES.CO.UK

5 HOLOFIT VR FITNESS

Treat someone to HOLOFIT Go – the perfect upgrade for your home rower, bike or elliptical machine. It makes workouts fun, interactive and social with 100+ options and a virtual coach to customise each. Get 20% off with code FITXMAS20.

FIND OUT MORE AT HOLODIA.COM/CONSUMER

6 WAKEcup

A wonderful Christmas gift that also gives a donation towards ocean conservation. Meet WAKEcup, the stylish alternative to single-use cups, bottles, bags and straws. Use code SUSTAINABLE10 at the checkout for a 10% discount.

FIND OUT MORE AT GLOBALWAKECUP.COM

7 AUDIO DETAIL
FROM MALVERN AUDIO RESEARCH

For lovers of the valve phono stage sound, a range of compact amps, hand-built in Great Malvern. Delivering a lower noise threshold but a fast, lively sound, vinyl has never sounded so good.

FIND OUT MORE AT MALVERNAUDIORESEARCH.CO.UK

8 G-MASTER GAMING DISPLAY FROM IIYAMA

Unleash the power of G-Master G2530HSU, the perfect gaming display. Black tuner function, FreeSync technology and 1ms response time lets you see every tiny detail and respond in an instant.

FIND OUT MORE AT IIYAMA.COM

9 MEADE TELESCOPES

Let the stargazers in your life follow that star with a telescope from Meade. With 40 years' experience of producing high quality models, a Meade Telescope is the perfect choice for easy, instant viewing and will make a wonderful gift.

FIND OUT MORE AT CURRYS.CO.UK

10 DRAGONFLY BY AUDIOQUEST

Keep music lovers happy with a DragonFly DAC, designed to plug in to your phone, tablet and computer to transform the sound of your favourite music through your headphones or hi fi.

FIND OUT MORE AT TINYURL.COM/Y6ANCOKM

11 SPACE ROVER INVENTOR KIT

The perfect gift for space cadets. This innovative kit lets you build a planetary rover using littleBits' electronic building blocks – then find limitless ways to customise your creation with the free littleBits Invent App.

FIND OUT MORE AT LITTLEBITS.COM

12 A NANNY GOAT

Know someone who's hard to buy for? For an original gift that has the power to transform lives, 'buy a goat' and your donation will help households and farmers in some of the world's poorest places.

FIND OUT MORE AT bit.ly/Christian-Aid

RACE TO VENUS

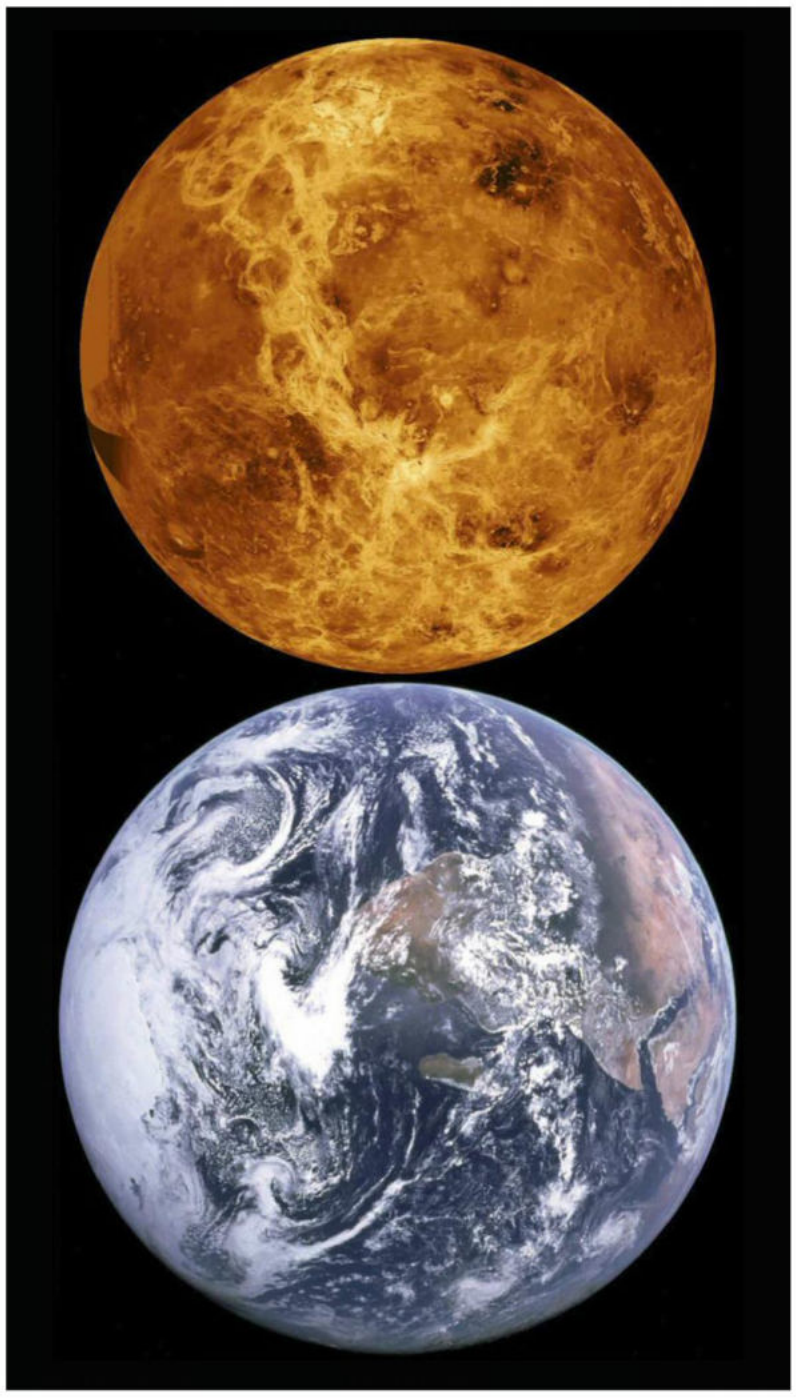
Scientists want to return to Venus, so they can try to find out why it morphed from a pleasant planet into a fiery and inhospitable hell hole

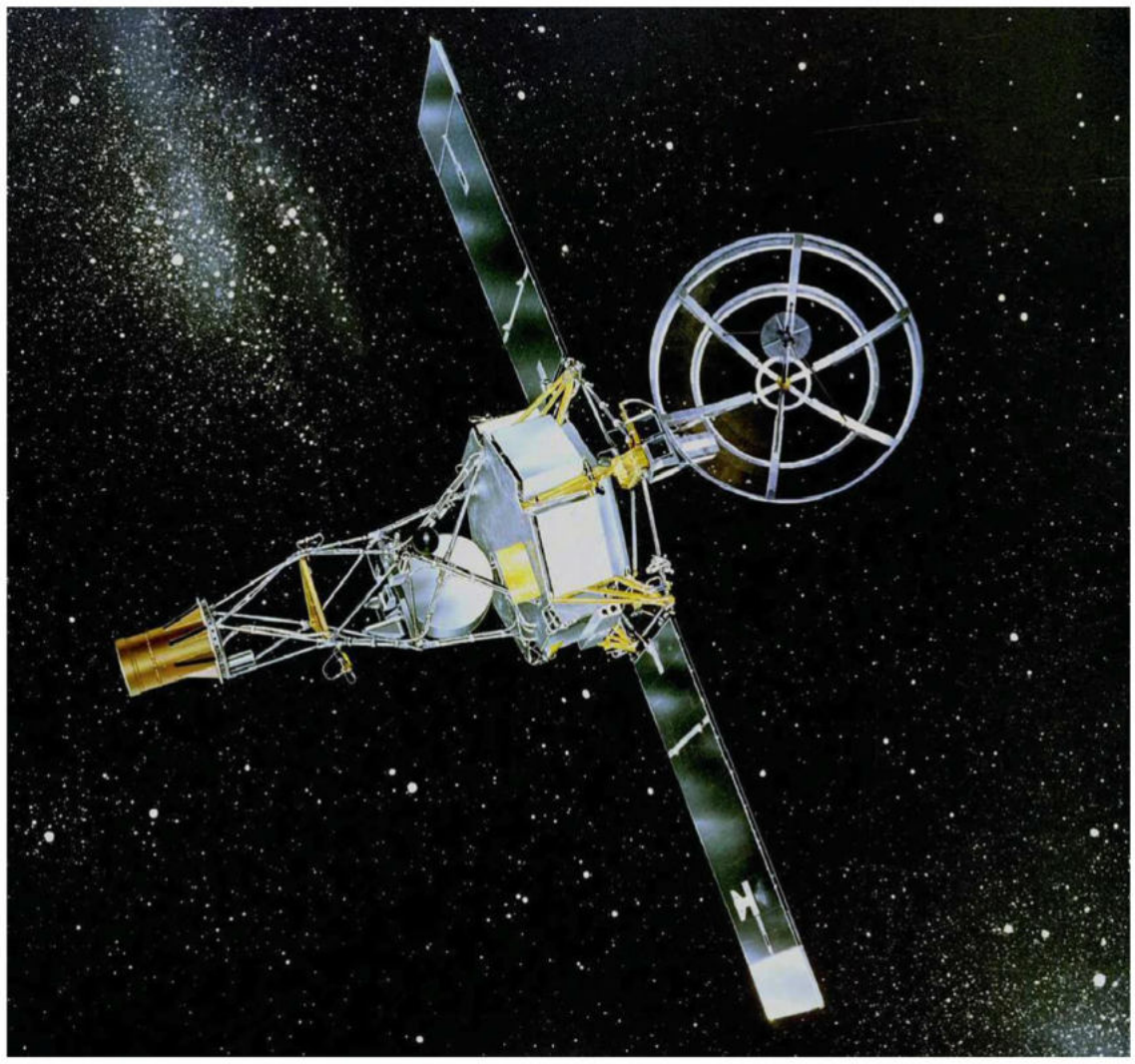
WORDS: ABIGAIL BEALL

We have a toxic twin. Venus is the closest planet to Earth, both in size and often in distance, yet the surface conditions couldn't be more different. One planet is home to abundant life; the other is hellishly hot, choked by an atmosphere of carbon dioxide that creates a surface pressure equivalent to being almost one kilometre underwater on Earth.

However, things weren't always this way. Once upon a time, Venus might have had a similar climate to Earth, complete with water oceans and plate tectonics.

Finding out what went wrong with Venus is the question behind a fresh surge in missions to explore the planet. It's an endeavour that promises to shed new light on how planets become habitable, and could even guide our search for life elsewhere in the cosmos. ➤





"FOUR AND A HALF BILLION YEARS AGO, THINGS LOOKED DIFFERENT. YOU'D SEE WATER AND A PLEASANT CLIMATE ON MARS, EARTH AND VENUS"

Over the past 20 years, exploration of Venus has fallen out of favour. Missions to Mars, Jupiter, Saturn and Pluto have dominated the headlines, and poor old Venus has become something of a forgotten planet. But this wasn't always the case. In fact, in the early days of space exploration, Venus was our first target…

ABOVE LEFT Earth and Venus are extremely similar in size, giving them the moniker of the 'twin planets'

ABOVE NASA's Mariner 2 flew past Venus in 1962 and was the first space probe to encounter another planet

EARLY EXPLORERS

In 1962, NASA's Mariner 2 spacecraft flew past Venus, becoming the first space probe to encounter another planet. Five years later, the Soviet Venera 4 probe entered the Venusian atmosphere, becoming the first to enter the atmosphere of another world. The same year, NASA's Mariner 5 set off on the space agency's second successful flyby mission. The exploration of Venus was in full swing.

What followed was a series of missions, some failures but mostly successes, to find out more about this planet that, at first glance, appeared so similar to our own. But from the 1980s onwards, the pace slowed down considerably. NASA's last dedicated mission to Venus was the Magellan spacecraft, which launched in 1989. The reason for this drop-off? As the data started to come back from our twin planet, astronomers interpreted the high temperatures, suffocating atmosphere and impact craters they saw on the surface as evidence that Venus was biologically and geologically dead – and therefore of limited interest to scientists searching for extraterrestrial life or Earth-like geology. The pristine condition of most of Venus's impact craters, for instance, indicated a comparatively young surface, which suggested that some kind of global, volcanic event in the planet's history had completely resurfaced the planet, resulting in a dramatic reduction in geological activity.

This idea, however, is still up for debate. "Since then, a lot of people have done [computer] modelling that indicates that this is a very unlikely interpretation," says Dr Sue Smrekar, a planetary geophysicist at NASA's Jet Propulsion Lab, and self-confessed 'Venusophile'. Instead of one huge event, says Smrekar, "you could have 'steady state' [smaller and reoccurring] processes of volcanism to produce the impact crater record." Settling this debate, and discovering the true story of Venus's history, is the motivation behind a proposed NASA mission that's being led by Smrekar, called VERITAS.

NASA X3

SAME PLANET, DIFFERENT CLIMATE

Today, the average surface temperature on Venus is 462°C. But the planet wasn't always such a hot mess. When the Solar System was in its early stages, four and a half billion years ago, things looked different. "You'd see water and a pleasant climate on Mars, Earth, and Venus, most likely," says Dr Richard Ghail at Royal Holloway, University of London, who is lead scientist of a proposed European Space Agency (ESA) mission to Venus, called EnVision.

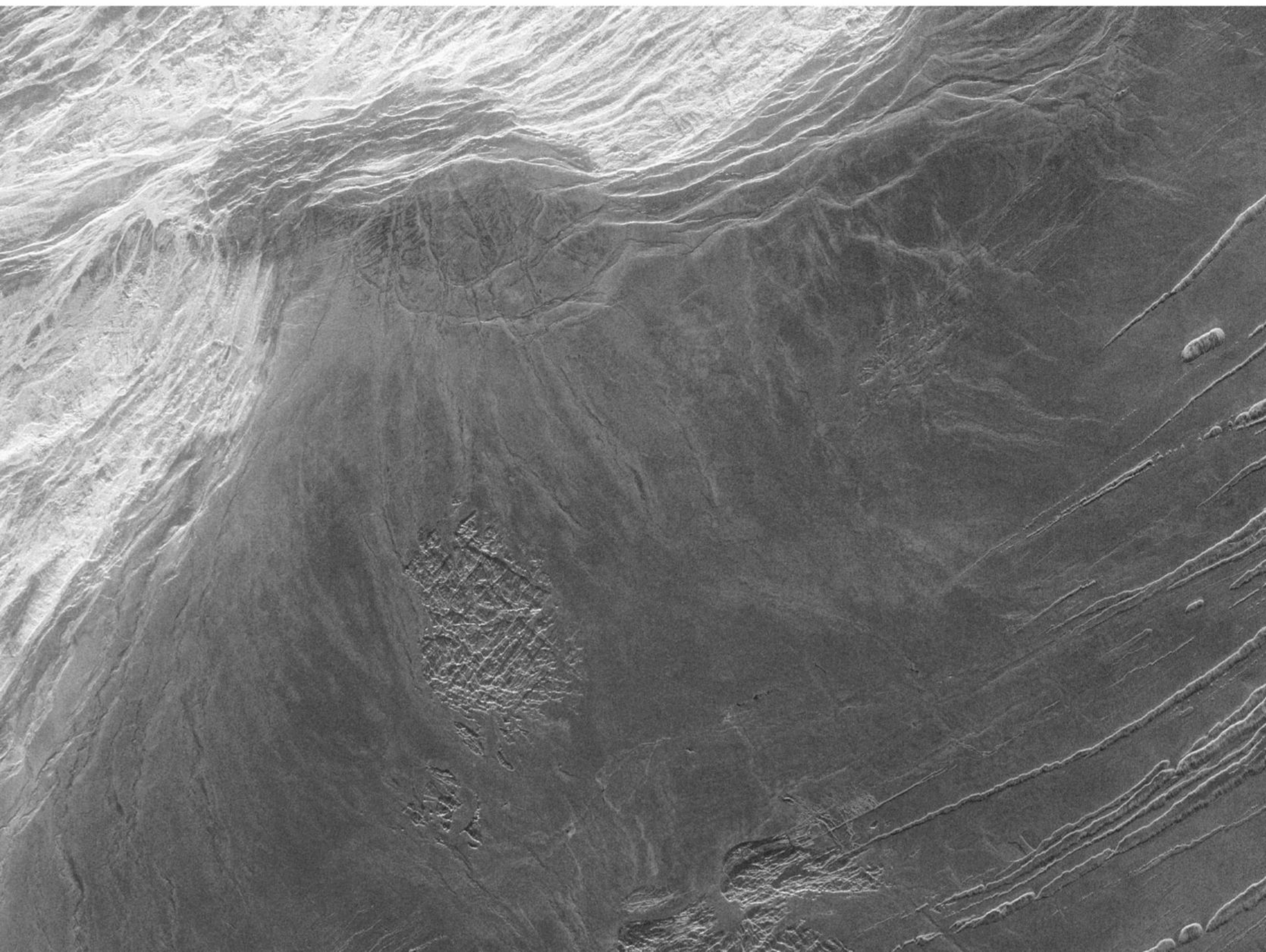
Two billion years later, it was a different story. Mars was basically dead and Earth was a frozen snowball, says Ghail. Earth was active as a planet, in the geological sense, but frozen solid, resembling how Jupiter's moon Europa looks today.

"Venus probably looked like a hot version of the Earth," says Ghail. "It still had oceans but they were evaporating… it was starting to get really unpleasant." At this point, "you'd think all three of these planets were doomed biologically. And yet, Earth came out of that and into this new phase where life appeared," he adds.

Understanding Venus's geological history will be crucial to piecing together the contrasting fortunes of the two planets. While Venus is not known to be geologically active today, its past patterns of volcanic activity will be a vital clue in helping us find out more about the planet. The amount of volcanism could be linked to the amount of toxic sulphur dioxide in Venus's atmosphere, for example, which is a key reason why it is uninhabitable. "Ultimately, we want to understand why Venus and Earth are different," says Smrekar.

The surface of Venus has not been mapped since NASA's 1989 Magellan mission. "We now have better topography maps for Pluto than we do for Venus, so it's time for an update," says Smrekar.

This is where VERITAS (Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy) comes in. The aim of this mission, which is currently being considered for funding by the agency's Discovery Program (a series of lower-cost missions to explore the Solar System), is to use radar and measurements of the planet's thermal properties to produce ➤



BELOW The Maxwell Montes mountain range on Venus includes the planet's highest point, Skadi Mons

DESTINATI

VENUS

AVERAGE DISTANCE FROM SUN: 108,200,000KM

RADIUS: 6,052KM

MASS: 4.87 × 10^{24}KG

AVERAGE SURFACE TEMPERATURE: 462°C

PROPORTION OF CARBON DIOXIDE IN ATMOSPHERE: 96.5 PER CENT

SURFACE PRESSURE: 92 BAR

SHUKRAYAAN-1

POSSIBLE LAUNCH DATE: EARLY 2020s
SPACE AGENCY: ISRO (INDIA)
AIM OF MISSION: ORBITER TO STUDY THE SURFACE AND ATMOSPHERE OF VENUS, POTENTIALLY INCLUDING RADAR, A PLASMA WAVE DETECTOR AND A CLOUD MONITORING CAMERA.

VERITAS

POSSIBLE LAUNCH DATE: 2021
SPACE AGENCY: NASA
AIM OF MISSION: ORBITER TO CAPTURE GLOBAL, HIGH-RESOLUTION MAPS OF TOPOGRAPHY AND ROCK TYPE ON THE PLANET'S SURFACE.

DAVINCI

POSSIBLE LAUNCH DATE: 2021
SPACE AGENCY: NASA
AIM OF MISSION: DESCENT PROBE TO UNDERSTAND THE HISTORY OF VENUS'S ATMOSPHERE AND STUDY THE CHEMICAL PROCESSES IN THE LOWER ATMOSPHERE.

EXPLORATION OF VENUS: THE HIGHLIGHTS SO FAR

DEC 1962

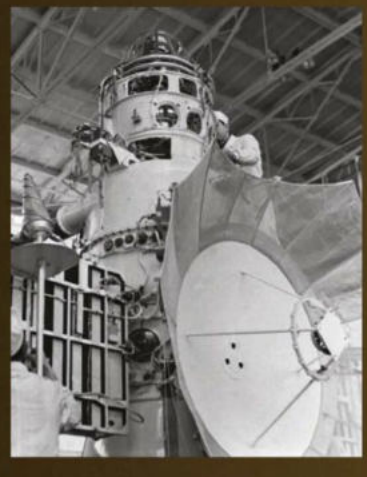
NASA's Mariner 2 is the first successful flyby mission of Venus – or any planet – sending back information about the Venusian atmosphere.

OCT 1967

Venera 4 is the first successful Soviet mission to Venus. The space probe carries out the first chemical analysis of the planet's atmosphere, revealing it to be mostly carbon dioxide.

JUL 1972

The Soviet Venera 8 is the first space probe to successfully land on the surface of Venus. It sends back data for 50 minutes.

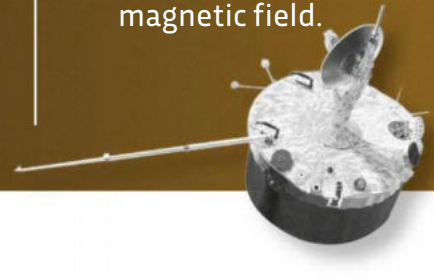


OCT 1975

Venera 9 is the first spacecraft to orbit Venus, while its accompanying lander is the first to send pictures from the surface of another planet.

DEC 1978

Pioneer Venus 1 is NASA's first Venus orbiter, carrying out a range of tasks including mapping the planet's surface and measuring its magnetic field.



ON VENUS

EARTH

AVERAGE DISTANCE FROM SUN: 149,600,000KM

RADIUS: 6,371KM

MASS: 5.97 × 10^{24}KG

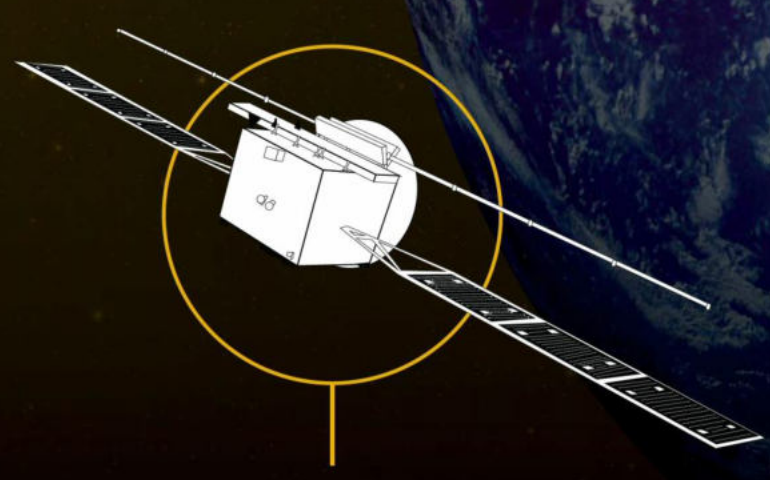
AVERAGE SURFACE TEMPERATURE: 14°C

PROPORTION OF CARBON DIOXIDE IN ATMOSPHERE: 0.04 PER CENT

SURFACE PRESSURE: 1.01 BAR

LLISSE

POSSIBLE LAUNCH DATE: 2023
SPACE AGENCY: NASA
AIM OF MISSION: SMALL PROBE CAPABLE OF SURVIVING ON THE SURFACE OF VENUS FOR DAYS, CAPTURING INFORMATION ABOUT THE PLANET'S WEATHER.



ENVISION

POSSIBLE LAUNCH DATE: 2032
SPACE AGENCY: ESA
AIM OF MISSION: ORBITER TO STUDY VENUS'S ATMOSPHERE, HISTORY AND CLIMATE USING RADAR IMAGING.

VENERA-D

POSSIBLE LAUNCH DATE: 2026 - 2031
SPACE AGENCY: ROSCOSMOS (RUSSIA)
AIM OF MISSION: ORBITER, FOR DETAILED OBSERVATIONS OF THE PLANET'S ATMOSPHERE; LANDER, TO SPEND AT LEAST TWO HOURS ON THE SURFACE.

JUN 1985

The Soviet space probes Vega 1 and Vega 2 send landers down to Venus, before using the planet's gravity to carry out a flyby of Halley's Comet.

AUG 1990

NASA's Magellan spacecraft enters orbit around Venus, where it stays for four years, carrying out high- resolution radar mapping of the planet's entire surface.

APR 2006

ESA's Venus Express enters orbit around Venus, and is the first spacecraft to carry out long-term observations of the planet's atmospheric dynamics. It finds evidence for an ozone layer, lightning, and a huge, shape-shifting vortex at the planet's south pole.

DEC 2015

The Japanese Akatsuki space probe enters orbit around Venus after a previous failed attempt in 2010. It is currently studying the planet's atmospheric dynamics and cloud structure.

high-resolution topography maps and information on rock types across the planet's entire surface. This will help to pin down the nature of Venus's volcanic past, but also answer the question of whether it ever had plate tectonics, and what role water played in its history.

Venus's surface has a handful of huge plateaus. "If these features are similar in composition and origin to those on the Earth, it tells us that Venus underwent some very Earth-like processes, and that water was really important in shaping the [Venusian] surface," says Smrekar. She adds that by examining the types of rock on Venus, we could discover whether or not water was once there. For example, certain rock types can only be created when lava meets water. Meanwhile, studying whether Venus's surface is broken up into continent-like features will show whether it once had plate tectonics. On Earth, plate tectonics play an important role in the carbon cycle, helping to remove carbon dioxide from the atmosphere. So a lack of plate tectonics on Venus could help to explain why this planet's atmosphere contains so much carbon dioxide (96.5 per cent), which is in turn responsible for Venus's runaway greenhouse effect.

"WE NOW HAVE BETTER TOPOGRAPHY MAPS FOR PLUTO THAN WE DO FOR VENUS, SO IT'S TIME FOR AN UPDATE"

VERITAS is just one of a suite of missions being proposed to explore Venus. Another in NASA's Discovery Program is DAVINCI (Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging). If selected, this mission would involve dropping a descent probe through the atmosphere and measuring the chemical composition down to the surface in high-fidelity, providing information on the origin and evolution of the Venusian atmosphere, and helping to answer the question of why it's different to that of Earth. DAVINCI lost out to two other missions, Psyche and Lucy, in the 2015 round of proposals, but was resubmitted in July this year.

Meanwhile, another proposed NASA project, not connected to the Discovery Program, is LLISSE (Long-Life In-situ Solar System Explorer). This began in 2017 as a project to develop small landers and instruments capable of surviving on the surface of Venus for days, as opposed to the minutes of previous missions.

"This capability will revolutionise our understanding of Venus by allowing us to see how conditions change over time, giving us new insight into the dynamic processes occurring in Venus's atmosphere," says Dr Lori Glaze, director of NASA's Planetary Science Division, and part of NASA efforts to support LLISSE. "Such information is critical to getting at the history of water and possibly habitable periods in Venus's past. But this requires electronics that can survive temperatures of over 470°C."

Standard, silicon electronics break down quickly under these conditions, so LLISSE would use cutting-edge silicon carbide semiconductors. The aim is to have a probe on the surface of Venus, collecting data about the planet's weather in situ – something that would be a breakthrough moment for space exploration.

FUTURE OUTLOOK

Presently, none of these missions are set in stone. Out of all the proposed Solar System missions in NASA's Discovery Program in 2019, five will reach the next stage of development, and one will ultimately go ahead, with a launch slated for 2021. Meanwhile, it's hoped that the LLISSE probe will be ready to go in 2023, likely taken to Venus by another mission.

ESA also wants to study the Venusian surface using radar. The

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EnVision spacecraft would spend four years orbiting the planet, looking at how much volcanism is taking place and whether the surface is moving, and characterising the interior structure of the planet, too. All of this will help to build a more detailed picture of the differences – and similarities – between Venus and Earth. "It would be really exciting to do real comparisons with Earth," says Ghail, referring to the fact that the Venus data will be of a similar resolution to the geological data we already have for Earth.

Part of the EnVision mission would include trying to spot the Soviet Venera landers, which sent images of the surface back to Earth. "We want to identify where they are [after they crash-landed on the surface], and then image their immediate surroundings to make sense of the images," says Ghail. This will enable researchers to link the chemistry of the rocks the landers analysed to a specific area on Venus.

EnVision is currently in its first phase of study, which will end in spring 2021. If it is selected, it will launch in 2032, arriving at Venus after a five-month cruise. But NASA and ESA are not the only space agencies with their eyes on Venus. Russia wants to continue its exploration of the planet with Venera-D, a proposed mission which includes an orbiter and a lander. And the Indian Space Research Organisation (ISRO) is planning an orbiter too, called Shukrayaan-1.

All of these missions promise to help us answer the question of how Venus became so different from Earth. But they also have their eye on an even bigger question: is there life elsewhere in the cosmos? Once we have a better idea of the processes that can make a planet habitable, exoplanet hunters will have a better idea of where to look for life on other worlds.

"We need to understand what happened to Venus, and how common this fate is, to estimate how many potentially habitable planets there are," says Prof Abel Méndez, director of the Planetary Habitability Laboratory at the University of Puerto Rico at Arecibo.

More clues will come as astronomers improve their ability to detect and measure exoplanet atmospheres. "We can't tell the Earths from the Venuses right now," says Méndez. A fundamental difference between the two planets is Venus's suffocating, extra-thick atmosphere. This [thickness] is "something we can't measure yet for any Earth-sized planet, but we are getting closer," he says.

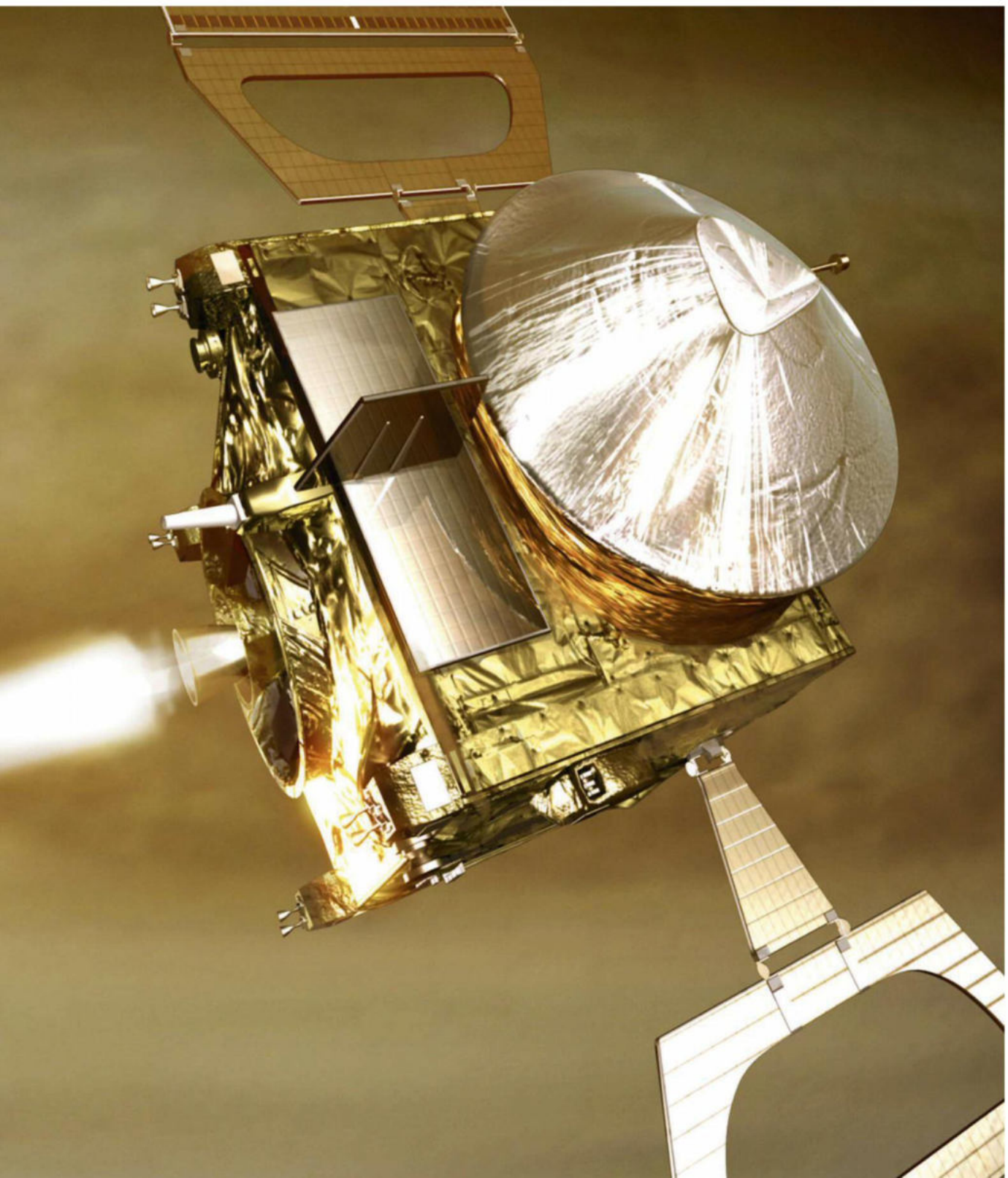
Once astronomers have more information about exoplanet atmospheres, they'll be able to combine this with measurements of the planet's distance from its host star in order to gain a better prediction of how likely it is to be habitable. Because, as Earth and Venus have shown, distance isn't everything. "Even Earth with a Venus-like atmosphere would be too hot for life," says Méndez.

It may be a while before we have definitive answers to how many Venuses there are in the cosmos, and why two planets so close to each other could have such vastly different fates, but it seems that the gaze of the world's astronomers is finally turning back towards our closest neighbour. Sometimes, it turns out that the most interesting things are lying right under our noses. **SF**

FAR LEFT The LLISSE probe, visualised here, is pencilled for launch in 2023 and would be able to survive on Venus's surface

LEFT Venus, illustrated here, has the hottest surface of any planet in the Solar System

BELOW Venus Express, visualised here, was the first ESA mission to explore the second planet from the Sun



by **ABIGAIL BEALL** *(@abbybeall)*
Abigail is a science journalist, based in Leeds.

DISCOVER MORE

BBC SOUNDS *Listen to former NASA chief scientist Ellen Stofan talking about her research into Venus in this episode of* The Life Scientific ***bit.ly/LS_ellenstofan***

TO DEATH AND BACK

No one can give a first-person report on what it's like to die, but near-death experiences and drug trips could offer us a glimpse beyond the veil

by DR CHRISTIAN JARRETT

What is it like to die? In 2012, the retired US neurosurgeon Eben Alexander reassured us in his book *Proof Of Heaven* that it is a blissful experience. Of course, he wasn't speaking from beyond the grave. His claims were based on what he said had happened to him during a week-long coma a few years earlier. While close to death and with his *E. coli*-infected brain rendered virtually inactive, Alexander said he had a transformative experience that included travelling through a black void "brimming over with light: a light that seemed to come from a brilliant orb". He also described being comforted on his journey by a young woman with high cheekbones and blue eyes, who told him he had nothing to fear and that he was "loved and cherished, dearly, forever".

Alexander's fantastical account divided opinion. Millions rushed to buy his book, and the US magazine *Newsweek* splashed his story on their cover with the headline "Heaven is real". Yet eminent neuroscientists such as Sam Harris and Colin Blakemore queued up to pick holes in the account and to present a more biologically grounded version of events. "Of course, the brain does funny things when it's running out of oxygen," wrote Blakemore at the time. "The odd perceptions are just the consequences of confused activity in the temporal lobes."

Alexander's story contains several features of what researchers today call a 'near-death experience' ➤

WARNING

LSD, DMT and psilocybin are Class A drugs according to UK law. Anyone caught in possession of such substances could face up to seven years in prison, an unlimited fine, or both.

Information and support for those affected by substance abuse can be found at **bit.ly/drug_support**

(NDE). The term was coined by the US psychologist and philosopher Raymond Moody in his 1976 bestselling book *Life After Life* in which he presented the accounts of 150 people who'd come close to death, noting that they often contained the same features, such as: a bright light; an out-of-body experience; the comforting presence of other people; feelings of wellbeing and reduced fear. It's possible to trace similar depictions further back in time, however. For instance, *Ascent Of The Blessed*, painted by Hieronymus Bosch early in the 16th Century, features a bright light at the end of a tunnel.

Just as Alexander's story split opinion, so too have NDEs more generally. Some scientists, such as Dr Bruce Greyson, professor emeritus of psychiatry and neurobehavioural sciences at the University of Virginia and co-author of *The Handbook Of Near-Death Experiences*, believe that they challenge a purely physical account of human experience. NDEs "…present us with data that are difficult to explain by current physiological or psychological models," he wrote in 2013.

However, many others, such as Dr Charlotte Martial at the Coma Science Group at the University Hospital of Liege, and Chris Timmermann at the Imperial College Psychedelic Research Group, believe there *is* a scientific, neurochemical explanation for NDEs. Martial says she is "very convinced" by such explanations, though Timmermann cautions that "definite proof might be impossible with our current tools, because it would require for researchers to probe in the brains of human beings at the moment of death, which is unethical."

DRUGS AND NEAR-DEATH

The neurochemical account is given weight by a curious observation. Many of the key features of an NDE are recounted not only by people who have nearly died, but also by people who have taken psychedelic drugs. These include, but are not restricted to, psychedelics that act on the serotonergic system in the brain (serotonin is a neurotransmitter that's involved in mood and perception, among other functions). Such drugs are known as the 'classic psychedelics', and include LSD (lysergic acid diethylamide), psilocybin (the hallucinogenic compound in magic mushrooms) and DMT (dimethyltryptamine or 'spirit

"THE PARALLELS BETWEEN PSYCHEDELIC TRIPS AND NEAR-DEATH EXPERIENCES HAVE BEEN OBSERVED FOR DECADES"

ALAMY X2

LEFT The painting *Ascent Of The Blessed* depicts a bright light and the presence of other people – similar to accounts of near-death experiences

RIGHT A shaman in the Amazon pours ayahuasca brew in readiness for a spiritual ceremony

molecule', which is found in several plants located in the Amazon basin).

Psychedelic compounds have been used throughout history for spiritual adventure or to visit the afterlife. In the 16th Century, the Spanish Franciscan friar and missionary Bernardino de Sahagún described the use of mushrooms by indigenous people in Mexico leading them to experience "terrifying and amusing visions" and how "some saw themselves dying in a vision and wept". Further south, in traditional ayahuasca ceremonies in the Amazon rainforest, shamans still use a brew made out of DMT-containing *Banisteriopsis caapi* vine (they call it the 'vine of the dead') to contact spirits. In traditional cultures in central Africa, meanwhile, the psychedelic shrub iboga is used to induce an NDE as part of initiation ceremonies designed to broaden young people's minds.

Indeed, the parallels between psychedelic trips and NDEs have been observed for decades. It's notable that the second LSD trip ever experienced by a human featured classic NDE elements, as recorded first-hand by the discoverer of the compound, the Swiss chemist Albert Hofmann on 19 April 1943. "My body seemed to be without sensation, lifeless, strange. Was I dying? Was this the transition? At times I believed myself to be outside my body, and then perceived clearly, as an outside observer, the complete tragedy of my situation," Hofmann wrote in his book *LSD, My Problem Child*. Elsewhere, the controversial former Harvard psychologist and psychedelic evangelist Timothy Leary even likened to trips to "experiments in voluntary death". Yet it is only very recently that scientists have begun to make a formal comparison, opening the possibility of using psychedelics to model the experience of near-death. "One can hypothesise that some endogenous molecules [ones that are generated by the human body] mimicking DMT or ketamine mechanisms could be released in life-threatening situations, when an individual experiences an NDE," says Martial.

DELVING DEEPER

In 2018 an international team led by Timmermann and Robin Carhart-Harris at Imperial College, and including Martial in Belgium, conducted a small trial in which they asked 13 volunteers to complete a well-established measure of near-death experiences, both after taking DMT and after taking a placebo pill (for example, they rated how much they felt separated from their body, how much they had a sense of peace, and whether they saw a bright light). The researchers also compared their volunteers' experience under the influence of DMT with the reports of 13 people who'd had a 'real' NDE after a life-threatening episode. They found that, after taking DMT, all 13 of their volunteers had effectively had an NDE based on their scores on the formal near-death questionnaire. The team also observed "few discernible differences" between the actual NDE cases and those induced by DMT.

HOW DO PSYCHEDELICS AFFECT THE BRAIN?

'Classic psychedelics' like LSD and psilocybin (found in magic mushrooms) are chemically similar to the neurotransmitter serotonin produced by the brain. Serotonin is involved in many neural functions including mood and perception. By mimicking this chemical's effects, the drugs exert their profound effects on subjective experience. DMT too acts via serotonergic pathways, but also through other routes – for instance, DMT binds with sigma-1 receptors that are involved in the communication between neurons. Meanwhile, ketamine – among many other effects – blocks NDMA receptors that are involved in the functioning of the neurotransmitter glutamate.

A key brain area for psychedelic drugs' effects appears to be the temporal lobe, the location of much emotional and memory functioning. For instance, removal of the front part of the temporal lobe (as a radical treatment for epilepsy) has been shown to prevent the psychological effects of taking LSD. Interestingly, abnormal activity in the temporal lobe, such as during seizures, can lead to trip-like and NDE-like experiences.

An effect shared by different psychedelic substances is that they increase the amount of disorganised activity across the brain – a state that neuroscientists describe as being 'higher in entropy'. One consequence of this is a reduction in the activation of a group of brain structures known collectively as the 'default mode network', which is associated with self-conscious and self-focused thought. One theory, then, is that psychedelics provoke a spiritual state of oneness with the world by increasing the brain's entropy and suppressing the ego-sustaining activity of the default mode network.

In a study published in March 2019, Martial led another international research group who took a different approach to the same question. They compared the similarity of the first-person descriptions of approximately 15,000 psychedelic trips with the retrospective first-person accounts of several hundred near-death experiences collected in Belgium and the USA. The similarities between the two kinds of experience were striking, with the NDE-like nature of the trips being especially apparent for people who'd taken one of the classic psychedelics, and most of all for people who'd taken ketamine – a so-called 'dissociative psychedelic' that is used in medicine as an anaesthetic. "In short, researchers now have indirect and more direct empirical evidence of certain neurophysiological mechanisms underlying NDEs," says Martial.

DEFINING DEATH

There are also similarities in the long-term effects of NDEs and many psychedelic trips. In both cases, people who have been through the experiences describe them as feeling 'realer than real', highly memorable and personally transformative. For example, a 2019 study involving dozens of people who'd had an NDE found that more than half considered it a self-defining memory. Similarly, psychedelic experiences have been shown to have lasting effects on personality, with people frequently describing their trip as one of, if not the most personally meaningful and spiritual events of their lives.

Martial and other researchers believe that the reason that many psychedelic trips are subjectively and psychologically so similar to NDEs is that, close to death, the brain releases chemicals that are the same as, or act in a similar way to, psychedelic compounds. Supporting this neurochemical account, DMT is known to be present in the brains of humans and other mammals, and a study published in the summer of 2019 even found that concentrations of DMT increased after cardiac arrest was induced in rats – perhaps as a function of its neuroprotective properties. Other scholars have made a proposal that a ketamine-like substance with a similar protective function might be released close to death.

There are also similarities in the level of changes seen in brain activity observed after cardiac arrest and following ingestion

RIGHT The academic Timothy Leary likened drug trips to "experiments in voluntary death"

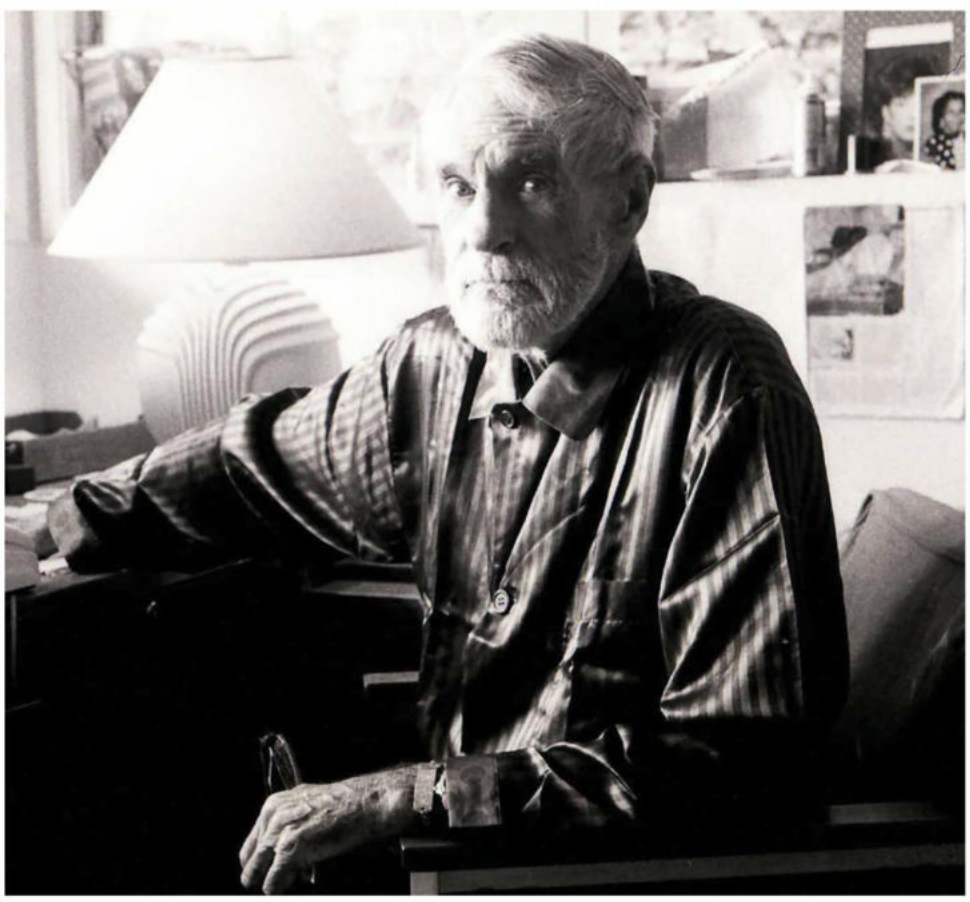
of psychedelics – in both cases, activity becomes more synchronised across the entire brain. It is speculated that this might be responsible for feelings of oneness with the world, also known as 'ego dissolution' (see box, left).

Not everyone is entirely convinced by the current proposed neurochemical explanations. For instance, the US pharmacologist and international psychedelics expert Prof David Nichols wrote a paper in 2018 in which he argued that the concentrations of DMT in the brain are too minute to be responsible for the psychoactive effects observed during NDEs. However, he says that "as a scientist, I do believe there is a neurochemical explanation for an NDE."

Timmermann, who led the aforementioned 2018 comparison of DMT trips and NDEs, hears Nichols's concerns but still believes that endogenous DMT may play a role in NDEs, possibly alongside other neurochemicals. And even if it turns out that chemicals such as DMT or ketamine are not involved in NDEs, he argues that psychedelics provide a useful model for studying the psychological experience of dying. "…[T]he experience of death is something which we are only beginning to become interested in from a scientific perspective, and thus models which can be safely used in controlled environments will be valuable for us to understand what these experiences are about and also why they might have such a strong impact on people's lives," he says.

The experience of death is still largely unchartered territory for science, and for obvious reasons (Martial and her colleagues noted wryly in their 2019 paper that "…dying is difficult to study under controlled laboratory conditions by means of repeated measurement"). Even if NDEs provide a window into the experience – and psychedelics can be used to model and investigate the same or similar processes – it's notable that the majority of people who are resuscitated after being close to death do not report NDE-type memories of what happened. "Since no one has actually died and come back to tell about it – I mean a death that is not reversed – we can't know whether DMT or ketamine are good models," says Nichols bluntly. "They may model the NDE, but we don't know whether an NDE is actually similar to the experience of dying."

"A KETAMINE-LIKE SUBSTANCE WITH A PROTECTIVE FUNCTION MIGHT BE RELEASED CLOSE TO DEATH"



MARTIN HIESLMAIR, GETTY IMAGES

On a positive note, the profound, NDE-like nature of many psychedelic trips has opened new avenues for helping alleviate existential suffering for people with terminal illnesses. Just as many people who emerge from classic NDEs subsequently report a dramatic loss of fear for the afterlife, so too do individuals who have enrolled in trials for psychedelic-assisted therapy for existential anxiety. Research groups around the world are now exploring these therapeutic possibilities, including at New York University, Imperial College in London and at the just-opened Center For Psychedelic Research at Johns Hopkins Medicine in the USA.

Could there be a risk that psychedelic research, by explaining NDEs in biochemical, rather than spiritual terms, will undermine the hope and relief that many people find in stories of NDEs? If the sensations of bliss, light and love come from neuroprotective molecules rather than being 'proof of heaven', is this an area of research best left alone? Like many working in this field, Dr Frederick Barrett at Johns Hopkins thinks not. "I generally disagree with the premise that explaining the biochemical basis of something undermines the subjective experience, meaning, beauty, terror, or otherwise the value of an experience," he says. "Does explaining the physics of centripetal acceleration make a rollercoaster any less exciting or terrifying? Not for me, and I would imagine: not for most." **SF**

by **DR CHRISTIAN JARRETT** *(@Psych_Writer)*
Christian is a senior editor at Aeon *magazine. His next book, on personality change, will be published by Simon and Schuster in early 2021.*

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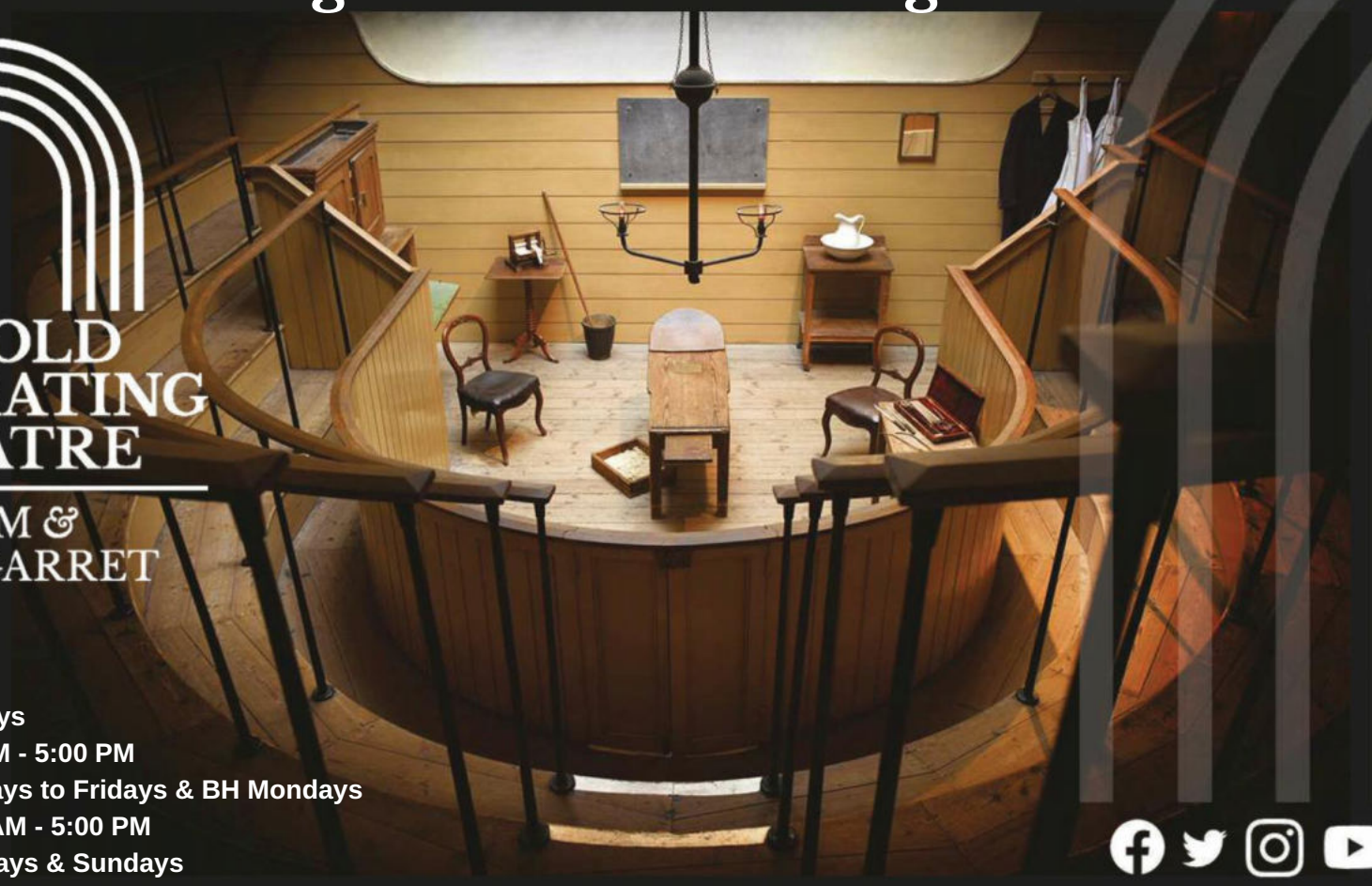

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COMMENT

CHRISTMAS IS COMING

Parties, puddings and boozy nights outs... is the festive period bad for your health?

PORTRAIT: KATE COPELAND ILLUSTRATION: DANIEL BRIGHT

One of the most likely times of the year to have a heart attack is on Christmas Eve. To arrive at this rather gloomy conclusion researchers from Lund University in Sweden looked back through more than 280,000 cases of myocardial infarctions reported as part of the SWEDEHEART study. They found that the risk of having a heart attack on Christmas Eve was 37 per cent higher than during a control period and that the risk peaked at around 10pm. They wondered if all the food, booze and cold nights in the weeks leading up to Christmas Eve might have contributed.

It is certainly true that all that extra fat and sugar you consume in the build up to Christmas will put a strain on your waist and your heart. But assuming you survive Christmas Eve, which part of the Christmas dinner is most likely to put your heart at risk?

You might think having turkey is going to be more heart-friendly than red meat. But it probably isn't. In a recent study, led by scientists from the Benioff Children's Hospital in Oakland, California, they asked 113 healthy men and women to eat either a diet rich in red meat, white meat or non-meat protein for four weeks, each in a random order. To their surprise they found that consuming red meat or poultry had a similar effect on blood cholesterol levels. The good news, however, was that

"Consuming red meat or poultry had a similar effect on blood cholesterol levels"

although eating these meats raised low density lipoprotein levels (ie LDL, commonly described as 'bad cholesterol') the effect was mainly to increase large particle LDL. This form of LDL seems to be fairly benign.

So what about the roast potatoes? I love roast potatoes, but for some reason people think it is a good idea to spend hours at the sink peeling potatoes on Christmas Day. It is not! Potato skin is rich in soluble and insoluble fibre. Fibre helps to bind bile acids, which your body produces to help digest food. This is great because bile acids are made of cholesterol. So just give those potatoes a wash. I will be basting my potatoes, as I do every year, in olive oil. Despite a widespread belief that it is bad to fry or roast foods in olive oil, it is a stable fat. It also seems to be good for the heart in a number of different ways. Consuming extra virgin olive oil lowers inflammation, prevents 'bad' LDL cholesterol from oxidising (which is a major step towards atherosclerosis) and has also been shown to help lower blood pressure.

Possibly the worst part of the meal is going to be the Christmas pudding. Rich in calories and sugar, it will push your blood sugars up and have a major impact on your triglyceride levels, which are another significant predictor of heart disease. On the other hand, it is delicious.

And on that cheerful note I wish you all a very happy Christmas! SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800* (£8.99, Short Books).

BBC TWO

COMMENT

JUST BE CURIOUS

You don't need to be scientifically trained to take part in valuable research

Currently, it's the beginning of the rainy season in the heart of Brunei, and I have never been so sweaty. Last night I was poking at insects larger than anything I've ever imagined in my nightmares, and despite this, I'm having the time of my life.

I'm on a taxonomy expedition at the Kuala Belalong Field Studies Centre in the Kingdom of Brunei Darussalam with a small group of entomologists, biotech researchers and laypeople like me. We are searching for new species in the rainforest under the guidance of a research organisation that's tackling the problem of dwindling grant money as an opportunity rather than a hindrance. Taxon Expeditions is one of a new crop of private entities that is tapping into the pockets of people who are science-curious, but not science-trained. We helped to fund this research, and we get to participate in it.

The electricity won't be on again for another four hours, but we are beavering away at DNA extraction and sequencing using an unbelievably futuristic device called the Nanopore MinION. It is portable, it is battery-powered, and it is sequencing the DNA from a tiny section of the rear leg of an *Agathia gigantea* moth in the time it takes to roast a mid-sized Christmas turkey.

I can't emphasise how remarkable this is. I spent a lot of time as a child dozing in my Snoopy sleeping bag under the table in my mother's lab as she worked on her PhD in developmental genetics. Sequencing DNA in the 1980s wasn't something that a person just did in a few hours, and it certainly wasn't done using a device that fitted in the palm of one's hand. And the result wasn't then immediately cross-referenced with an offline version of an online public database of more than 5.3 million 'DNA barcodes' to see if the organism being sequenced is a newly discovered species.

"It is sequencing the DNA from a tiny section of the rear leg of a moth in the time it takes to roast a Christmas turkey"

And the craziest thing about all of this is that the sequencer costs less than £1,000 from a company based in Oxford. I would recommend pairing up with an actual geneticist, a biotech expert and a real entomologist to make sense of the data, but the implications for the future of access to hands-on science are astonishing. Mark my words: we are less than a generation away from an army of layperson bio-prospectors working the field using a little bit of scientific training and a lot of YouTube knowledge.

But if a trip to the rainforest with an organisation like Taxon is out of the question, then you can still do research as close as your back garden. The same group that took me to the rainforest went to the Vondelpark in the centre of Amsterdam and identified a new wasp that had never been recorded by science. And yes, the sequencer – while less expensive than a high-end smartphone – does require a little more training than a touchscreen. But this kind of science is rapidly trickling down to the rest of us, so getting any science kit or apps in the hands of your kids or grandkids this holiday season is an investment. Because there's nothing like discovery to fuel the future. **SF**

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.

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INTERVIEW

THE SEARCH FOR A THEORY OF EVERYTHING

The two main theories of physics are at odds with one another. Einstein's General Relativity explains gravity, but it contradicts quantum theory: how we understand matter, atoms and particles. Theoretical physicist **Fay Dowker** tells **Amy Barrett** why the theories are incompatible, and how she intends to bring them together...

WHAT CHALLENGE DO PHYSICISTS FACE TODAY?

I am working on the problem of quantum gravity. We don't have a theory of quantum gravity yet. The challenge is to find one. It's a problem because our current two best fundamental theories in physics [General Relativity and quantum theory] are not compatible with each other. It's a strong statement to say they are contradictory, but I'm not afraid of saying that. Science advances by looking at contradictions between different pieces of our understanding, and it focuses on those contradictions in order to make progress.

Science tolerates contradictions, but not forever.

WHAT ARE THE CONTRADICTIONS INVOLVED IN THE PROBLEM OF QUANTUM GRAVITY?

Our best theory of gravity, currently, is General Relativity. Largely formulated by Albert Einstein, according to this theory, gravitational phenomena – such as the motions of the planets around the Sun, black holes, the motions of galaxies in the Universe – are manifestations of the geometry of a fabric that we call space-time.

Space-time is four-dimensional, and it's dynamical, so it has a life of its own. It is governed by laws of physics. It bends and it warps, and it ripples, and it carries energy. It is a physical entity in our current understanding of gravity.

> "Space-time is dynamical, so it has a life of its own. It is governed by laws of physics"

The way that it bends and warps is governed by the matter in the Universe. Depending on what matter there is, then space-time responds to it. If two black holes, for example, are in orbit around each other, spiralling in towards each other, then that will predictably create ripples in this space-time fabric called gravitational waves.

But the contradiction arises because our best and most fundamental understanding of matter is quantum mechanical. One of the essential features of quantum mechanics is that quantum mechanical events are inherently unpredictable. When a quantum mechanical event happens, we don't know in advance what the outcome will be. We know what the possibilities are, but we won't know which one will happen. Like if you go to a horse race, you know that one of the horses will win, but you don't know which one in advance. That quantum mechanical feature of matter is ignored by General Relativity. There's the contradiction: quantum mechanics says that matter behaves in a stochastic or random way, but General Relativity assumes that matter behaves in a predictable way.

SO HOW DO WE FIND A RESOLUTION TO THIS CONTRADICTION?

There's a global community of people working on quantum gravity. It's a strange situation at the ▶

moment, in which the experimental evidence pointing us in one direction or another in quantum gravity research is very, very scarce. It's hard to be guided by actual observations. For example, at the time of the Big Bang, roughly 13.7 billion years ago, when the matter in the Universe was in a hot, dense state… that realm is where both gravitational and quantum effects will be important. But it's very far from us in time. So, it's difficult for us to probe that era to get experimental evidence of what quantum gravity should be like.

CAN WE LOOK OUT INTO SPACE AND SEE THIS HAPPENING?

We can. So, cosmology – which is the study of the Universe at the largest scales that we can observe – is probably the most promising area that we can look to for evidence for different approaches to quantum gravity. I am hopeful that more and more cosmological data will, in the not so distant future, start to distinguish between different approaches, and we'll be able to be guided by that cosmological data in our research in quantum gravity.

WHAT ARE THE DIFFERENT APPROACHES?

I could divide them roughly into two… I mean, there's overlap between them, and there are scientists who work on more than one approach, but roughly speaking, they can be divided into two camps. There's one approach which comes from a tradition of particle physics, called string theory. These are physicists who have been focused on trying to understand matter at the most fundamental level, the standard model of particle physics. In string theory, the fundamental particles are conjectured to be different modes of vibration of a fundamental substance, which is one-dimensional. That's why it's called string theory; string is one-dimensional.

The other tradition takes the four-dimensional fabric of space-time as the starting point and to think about it as having a quantum mechanical nature. That stems from physicists working on General Relativity and gravitational physics, from which arises approaches that are more focused on space-time than they are on matter.

FOUR-DIMENSIONAL SPACE-TIME IS QUITE HARD TO GET YOUR HEAD ROUND.

Yes, yes, it is. It's a new worldview, a new way of thinking about the Universe. How do you get your head around three dimensions?

"The idea of four-dimensional space-time is that you need four numbers to pin down not just where you are but *when* you are … a particular instance of you. I mean, you *now*"

THREE DIMENSIONS IS SOMETHING THAT WE'RE ALL FAMILIAR WITH, RIGHT?

Yes, good. But what does it mean exactly? Well, what it means is that you can think of a thing, let me say… my teacup. To tell you where it is, I have to give you three numbers, three coordinates. How high it is above the floor, how far it is from the front wall, and how far it is from the side wall. That's what we mean by space being three-dimensional. If you want to pinpoint your position in Bristol right now on a map, you only need to give two numbers: the two coordinates of the coordinate grid on the map. So, the map of Bristol is two-dimensional, the space in this room around my teacup is three-dimensional.

The idea of four-dimensional space-time is that you need four numbers to pin down not just where you are but *when* you are. And what I mean by 'when you are' is not you, because you persist for many moments of time, but a particular instance of you. I mean, you *now*.

So, to say where that event is of you, you need to give four numbers. Three where you are in space, roughly speaking, and one of what time it is at that moment. Four-dimensional space-time is the collection of all these events.

HOW DOES THAT RELATE TO QUANTUM GRAVITY?

Well, first of all it relates to gravity. Space-time is the fundamental way that we understand gravity.

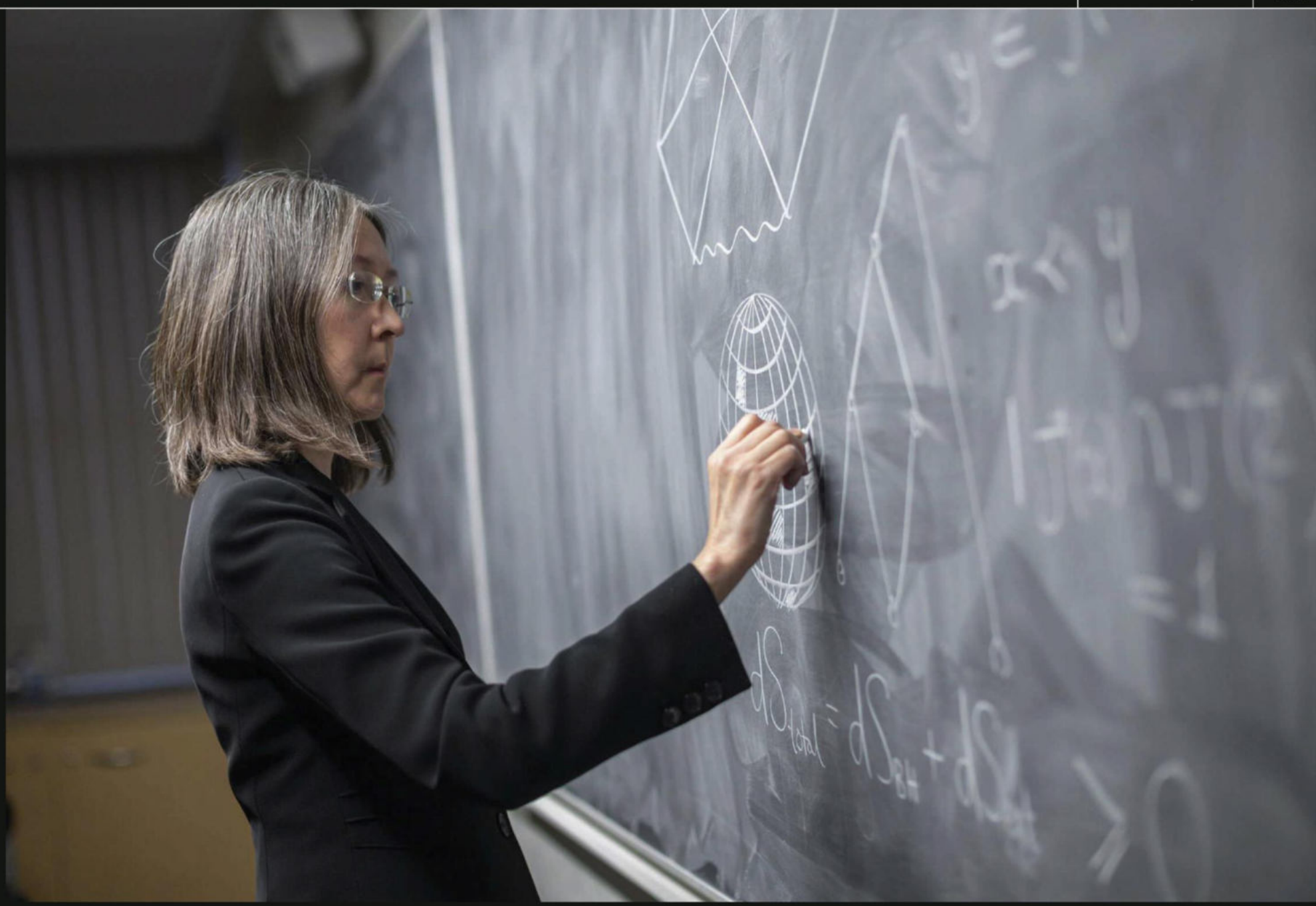
If you take all of the events in the Universe, then they form this four-dimensional fabric. The structure of that four-dimensional fabric manifests itself as gravitational phenomena. It explains gravity. It tells us why the planets orbit the Sun and why the galaxies behave as they do, why black holes exist, so this four-dimensional fabric of space-time is gravity.

Now, to understand quantum gravity, we have to understand quantum space-time. In General

PROF FAY DOWKER

Fay is a professor of theoretical physics at Imperial College London, working on several areas of theoretical physics as well as teaching and supervising students. As an undergraduate, Fay studied mathematics at the University of Cambridge. In 1990, Fay completed her PhD on space-time wormholes, under the supervision of Prof Stephen Hawking. She describes Stephen as her "teacher, mentor and friend" and delivered the eulogy at his funeral in 2018.

IMPERIAL COLLEGE LONDON



Relativity, space-time is smooth and continuous. But in the approach to quantum gravity that I work on, called causal set theory, the conjecture is that this smooth fabric is just an approximation to something which is fundamentally granular, bitty, pixelated. Fundamentally atomic. The word 'atom' means uncuttable. It's something you can't divide up any more. It's conjectured to be made of fundamental events that are the smallest possible events, and you can't cut them up any more.

Causal set is just the name we give to the mathematical, discrete, atomic object. The originator of causal set theory is my close colleague, a physicist called Rafael Sorkin.

HOW WILL THINKING ABOUT SPACE-TIME AS GRANULAR HELP SOLVE THE PROBLEM?

It relates to our understanding of the nature of the quantum world. There's no consensus on how to understand quantum theory, and but one approach is called 'the sum over histories'. It's associated very closely with the particle physicist Richard Feynman.

In this approach, you think about a quantum system in terms of things that can happen, events, and then histories, which are very detailed ways in which that event can happen. Feynman's sum over histories gives you a way of making predictions about those events, rules about how to calculate the probability of an event happening.

My colleagues and I are trying to base an understanding of the quantum physical world, on this sum over histories.

PROF STEPHEN HAWKING WAS YOUR PHD SUPERVISOR. WHAT WAS HE LIKE?

It was an amazing experience being his student. Stephen was a generous supervisor. He involved me in the work that he was doing, he gave me a great problem to work on, and he was approachable. I was a shy person and not good at putting myself forward, but he was not standoffish at all. He always made time for me. Even though I would often have to wait for a long time before seeing him because he was so busy, he always made it clear that science and his work and his research was a priority.

That was an important part of my PhD. The things that he taught me are still part of the way that I think about physics. The opportunities that I got from being his student also helped me enormously in my subsequent career. He just expected us to be involved in whatever he was doing at the time. I think that's very, very encouraging for a young scientist, to feel that they're part of something bigger. SF

ABOVE Prof Fay Dowker teaches theoretical physics at Imperial College London

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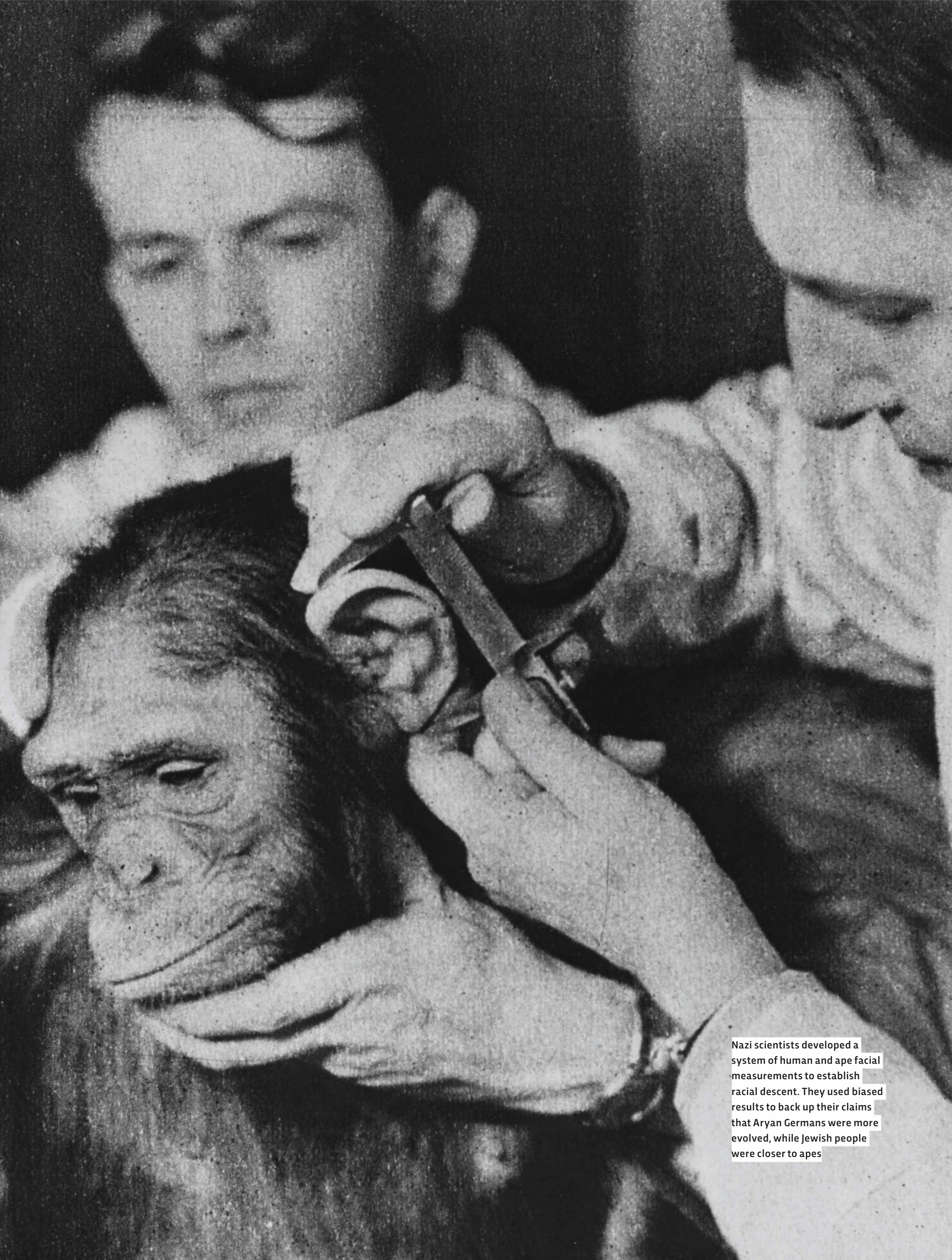

Nazi scientists developed a system of human and ape facial measurements to establish racial descent. They used biased results to back up their claims that Aryan Germans were more evolved, while Jewish people were closer to apes

FORBIDDEN MEDICINE

FROM NAZI MEDICINE TO GM BABIES, UNETHICAL RESEARCH HAS A DEEPLY PROBLEMATIC HISTORY. BUT WHAT SHOULD WE DO WHEN THE RESULTS OF THESE STUDIES COULD OFFER USEFUL SCIENTIFIC INSIGHT?

by TOM IRELAND

More than 30 years ago, in 1988, hypothermia expert Robert Pozos decided to unearth a document that society had tried to forget for almost 40 years. The 68-page report, compiled by an American army officer after WWII, contained details of the horrific experiments that Nazi doctors had conducted on many people in concentration camps.

These procedures, and the conduct of the Nazi doctors stationed at camps such as Dachau and Auschwitz, make for difficult reading. More akin to sadistic torture than research, the 'experiments' involved Jews being frozen to death, dissected alive, poisoned, wounded without anaesthetic, or sterilised – all supposedly in the name of advancing Nazi medicine.

After the details of Nazi war crimes were revealed at the Nuremberg Trials in the late 1940s, the documents relating to these atrocities were placed in the US Library of Congress. It was imagined that few would ever want to take such material off the shelves.

Yet Pozos, the director of a hypothermia research lab at the University of Minneapolis, believed the results of some of these evil studies could be used for good. He thought that the Nazi experiments on the effects of cold – conducted in the hope that it might help downed German fighter pilots survive longer in freezing waters – could be useful in his work developing treatments for severe hypothermia.

The Nazis had meticulously recorded the effects of cold up to the point of death, and trialled various methods of warming people up from the brink. It was the sort of data Pozos could never obtain with volunteers or patients in a trauma ward. It could help save lives. To some, the plan to use Nazi 'research' was an outrage. How could one treat accounts of human torture as if it were scientific data? Yet others, including some relatives of the victims, felt that if it meant some good could come from such terrible suffering, then it should be done. The dilemma kick-started an ethical debate that still divides opinion today: what should we do with the results of tainted or unethical research?

"IF SOME GOOD COULD COME FROM TERRIBLE SUFFERING, THEN IT SHOULD BE DONE"

Pozos was not the only person who wanted to access and analyse the Nazi research. Around the same time another hypothermia expert, John Hayward, went ahead and used results from Nazi experiments to help develop survival suits for fishermen working in freezing waters. And in 1989, the Environmental Protection Agency (EPA) in the US urgently needed to understand how phosgene gas affects humans. Phosgene is an important industrial chemical that's used in the production of certain plastics, but the EPA found there was barely any research on the subject of its toxicity in humans – except in Nazi literature.

The Nazis had gassed French soldiers with phosgene to record its ghastly effects; most of the prisoners died slow, painful deaths. With many US communities living near phosgene production plants, and amid rumours that Saddam Hussein was planning to use phosgene weapons on US soldiers, the EPA was forced to consider using the Nazis' murderous study in their assessment. Eventually, they backed down amid protests.

So, if good can come from an unethical experiment, should we use it? "There are two main concerns when considering whether to use this kind of data," says Dr Sarah Chan, a medical ethics expert at the University of Edinburgh. "Firstly, does it somehow make us ➔

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complicit in the wrong that happened if we use it? And secondly, by using it, are we legitimising or encouraging this behaviour in the future?"

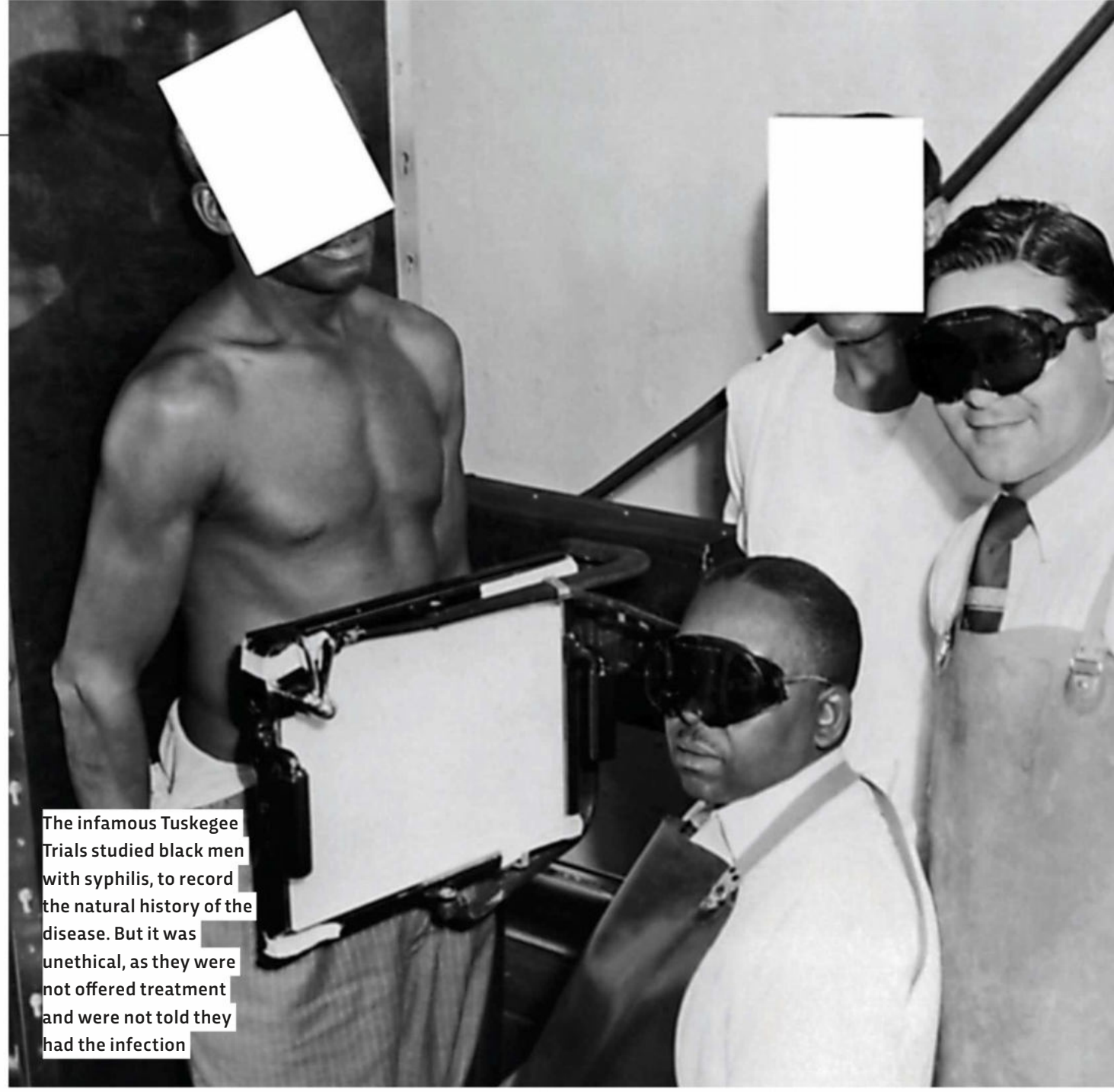
Chan believes that if people are sure that the answer to those two questions is no, then the use of results from tainted research can sometimes be justified.

"I think there are good arguments on both sides," says David Reisnik, a bioethicist at the US National Institute of Environmental Health. "In some cases, the data could be valuable for public health or advancing scientific research – but on the other hand it sets a bad precedent that data from unethical experiments will still be used. There are people who say you shouldn't use it, no matter what potential good could come from it, to send the message that ethics are important and should not be violated."

TOUGH DECISIONS

While Nazi experiments mark a low point in the history of medical research, many great advances in medicine were built on the back of research that seems completely unacceptable by modern standards. Early anatomists in England and Scotland, for example, faced a shortage of cadavers to use in their studies due to the regulations of the time. Many, including the great physician Robert Knox, learnt how the human body worked by studying corpses stolen from graves or even killed to order by the infamous murderers William Burke and William Hare. Edward Jenner, the country doctor and pioneer of vaccination, deliberately infected his gardener's son with cowpox as part of his early studies. Jenner's work is said by some to have saved more lives than any other experiment in history, and earned him a medal from Napoleon. A similar experiment today might earn him a prison sentence.

In both cases, the huge strides forward that resulted from terrible scientific practices cannot realistically be ignored or undone. Despite efforts to formalise the law around human experiments following WWII, shameful practices continued throughout the rest of the 20th Century. In the 1960s, the paediatrician Saul Krugman deliberately infected children who had intellectual disabilities with hepatitis in order to study how the disease spread. (He said the children's home where he conducted the study was so rife with the disease they "would have got it anyway", and was awarded several awards for his work.) During the infamous Tuskegee Trials, run by US health agencies, black men with syphilis were studied for decades without being offered treatment so that researchers could see how their disease progressed. It was not until the 1970s that the trial was finally shut down.



The infamous Tuskegee Trials studied black men with syphilis, to record the natural history of the disease. But it was unethical, as they were not offered treatment and were not told they had the infection

"THE DEFINITION OF 'ETHICAL' AND 'UNETHICAL' IS CONSTANTLY SHIFTING"

Chan believes that if society can use the results of tainted research without giving credit or credibility to those who conduct it, it could help reduce the lure of notoriety that attracts some people to act unethically. "If we think about what motivates people to engage in research we deem unethical, part of it must be that no matter how history condemns them, they will be known as 'the first person to...' or 'the author of'. It's about recognition. So we should think about how to use this knowledge without glorifying the acts that led to it."

There seems to be a rise in research deemed to be unethical. A recent example is He Jiankui, the Chinese biologist who shocked the world in 2018 by announcing he had helped create the first ever genetically-modified babies – twin girls born from embryos he had modified using the gene-editing tool CRISPR. Scientists around the world had previously agreed that the technology was not ready to be used in this way. As well as crossing many ethical and regulatory red lines, Jiankui did not even publish his

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There was widespread outrage when Chinese scientist He Jiankui announced he had helped create GM babies in 2018, but his work still made headlines

results. He simply posted a video about what he'd done to YouTube. His work still made headlines worldwide.

"The reality we have to deal with is that the dissemination of science now goes far beyond traditional academic publishing," says Chan. "No matter what we do to say 'you will not be credited, you will not be published in academic literature, we will not cite this research', the world at large still knows it has happened and wants to know if it worked."

SHIFTING DEFINITIONS

What makes things even more complex is that the definition of 'ethical' and 'unethical' is constantly shifting. Chan thinks it is important to consider what the scientific community deemed acceptable at the time the research was done. "If you do something wrong and at the time all your peers were also doing it and agreed it was okay, it is still wrong, but it is less wrong than doing something where all your peers are saying 'don't do that, it's horrific,'" says Chan. "There is an extra wrong in flagrantly breaching the standards of your community."

Reisnik, meanwhile, says it is likely that research we consider as ethically sound today could be viewed differently in future. "Just in my lifetime there have been huge changes in how human biomedical data is handled. It was routine to take tissue specimens for surgeries, use them in research and not tell people what they were doing," he says. "I don't know what the ethical issues of the future might be, but it is getting easier and easier to re-identify tissue and genetic data that we thought were completely anonymised. It's quite possible things will change, and what we think is okay today might not be considered okay 100 years from now."

Ultimately, when it comes to research that could save lives but comes from a terrible source, it can help to put yourself in the position of a person whose life depends on having the best information available. The BBC recently reported how lots of surgeons still use a book of anatomical illustrations produced by a Nazi physician, because it is considered to be one of the finest anatomical guides to the human body ever produced. *The Pernkopf Topographic Anatomy Of Man* was drawn using the corpses of people killed by the Third Reich, yet doctors want access to the best material to guide their work.

"If I was about to head into surgery," says Chan, "and I knew that I would have a better chance of survival if my surgeon could refer to this book, I would want them to refer to it."

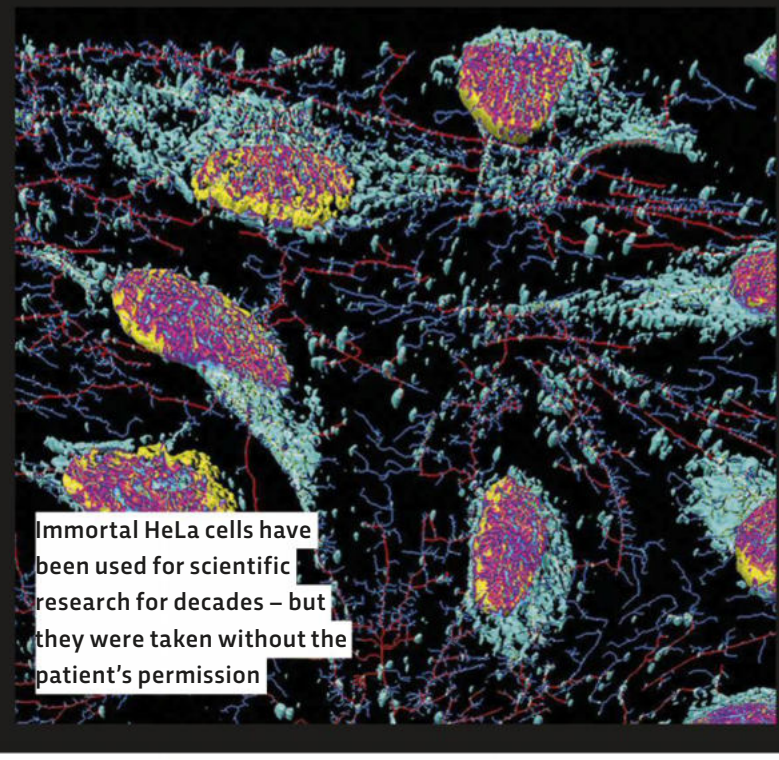
Would you? **SF**

by **TOM IRELAND**
(@Tom_J_Ireland)
Tom is editor of The Biologist *at the Royal Society of Biology.*

Who do HeLa cells belong to?

In 1951, a young black woman called Henrietta Lacks was treated for cervical cancer at Johns Hopkins Hospital in Baltimore, Maryland. As was common at the time, especially for black or poor patients, she was not told that the tissue from her biopsy might also be used for scientific research. Her cells turned out to be unlike anything doctors had ever seen: they grew quickly and could be kept alive outside the body, seemingly indefinitely. This remarkable 'immortalised' cell line (known as 'HeLa' after Henrietta Lacks) meant scientists could conduct detailed, long-term studies on human cells in the lab for the first time. Lacks died shortly after her biopsy was taken, and her family were not told about the HeLa cell line, even as it developed into a valuable (and profitable) scientific resource. The cells have been central to many important biological studies for almost half a century. It is only recently that bioethicists have started to address the questions raised by the case around consent, privacy, racism in research, and the ownership of biomedical data.

Today, regulations governing the use of human tissue and genomic data are far stricter, and Lacks's family has since become involved in decisions around the use of HeLa cells. But is it right that scientists around the world are still keeping cells descended from this woman alive, without her permission, years later?



Immortal HeLa cells have been used for scientific research for decades – but they were taken without the patient's permission

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WHAT IF...

(ROBOTS TOOK OUR JOBS?)

WORDS: **HAYLEY BENNETT**
ILLUSTRATION: **JOE WALDRON**

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Would we be happier in a world without work?

The futurist Martin Ford argues in his 2015 book *The Rise Of The Robots* that we are headed for a future of "technological unemployment", brought about by automation and algorithms. Soon enough, our jobs will be taken over by robots, and with artificial intelligence (AI) infiltrating every aspect of our lives, plans are being made for a post-work era. But without a regular routine and a wage, will we slump into sofa-ridden despair, live a life of leisure, or – just maybe – find time to solve the climate crisis?

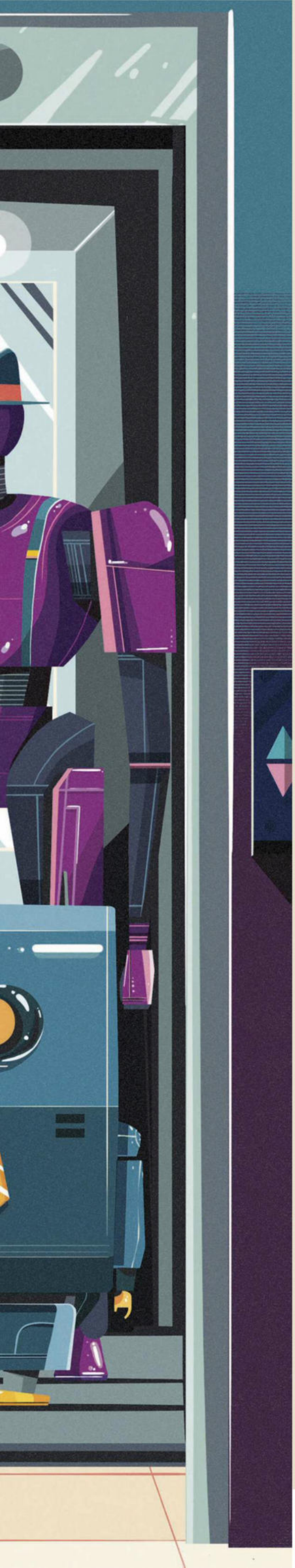
1

There will still be *some* jobs

How many of us will really lose our jobs to robots? A 2018 British Academy and Royal Society report found that 10 to 30 per cent of UK jobs are "highly automatable", meaning they could soon be done by machines. Manufacturing has already encountered substantial losses; fast food preparation, admin and accountancy jobs are up next, according to the report, while drivers will eventually be replaced by autonomous vehicles. However, the report also predicts that humans will hold on to some lower-paid and manual jobs, such as caring for children and the elderly, and plumbing.

A look to the past suggests we're unlikely to lose all of our jobs, says Dr Luke Martinelli, a policy researcher at the University of Bath. This was predicted in the 19th Century and again in the 1930s, and it didn't happen. "So there's a [view] that humans will always have work – we'll just do different things," says Martinelli, suggesting we'll keep the more creative jobs and those requiring interpersonal skills. But then, he adds, the more pessimistic stance is that robots could feasibly do anything. On the creative front, for example, machine learning systems are already churning out paintings, sculptures, music and even film trailers that are indistinguishable from human art.

Taken to its logical conclusion, this scenario would eventually see us bowing down before our robot rulers. In fact, New Zealand already has a virtual, AI-powered politician called Sam, who can talk – without mistruth or misrepresentation – to prospective voters, and is reportedly running for parliament in the next election. Maybe that's one job that robots could do better...



2

We'd be pretty darn miserable

In 1929, an entire community in Austria became unemployed overnight when the textiles factory that provided work to almost everyone in the village of Marienthal closed down. This became the inspiration for social psychologist Marie Jahoda's life's work, crystallised in her 'deprivation theory' of unemployment. Jahoda, who spent many weeks with the locals in Marienthal, proposed an explanation for the hardship people experience when they are unemployed. Work doesn't just provide money, but also fulfils basic psychological needs including social contact, status and time structure. Yet no one rigorously tested Jahoda's ideas until Dr Andrea Zechmann and her colleague Prof Dr Karsten Paul at the Friedrich-Alexander University Erlangen-Nürnberg in Germany and started speaking to hundreds of people looking for jobs. Their 2019 study confirmed that being out of work causes distress due to seven unmet psychological needs, the most important being collective purpose: work makes our lives meaningful. This suggests that robot-induced mass unemployment would make us miserable. How miserable? We can only rely on what little we know from long-term studies of unemployment. "People's wellbeing is on a plateau for months or even some years afterwards," says Zechmann. "This obviously means that many people who are unemployed for a long time find themselves in a depression." Of course, this is in a world where people continue searching for work. What happens without any prospect of re-employment is difficult to predict.

3 There'd be more time for... other things

One way to plug a giant, work-sized hole in our daily schedules would be to fill it with more work, just not of the paid variety. "In a post-work world, what seems important to me is that people can substitute employment with a purposeful activity," says Zechmann. "For example, this could be engaging in voluntary work, which some people already do, because it pertains to collective purpose – you can work to a greater goal."

Perhaps we could give our lives purpose by helping the robots to solve some of the world's most pressing problems. In the days before science became a bona fide profession, there were unfunded or self-funded 'natural philosophers'. Even as late as the 1930s, Guy Callendar, who discovered climate change, was more of a hobbyist than a qualified academic. Today, volunteers or 'citizen scientists' monitor butterfly populations and beach litter. The jobless could swell the ranks.

For those who prefer not to spend their free time working, how about looking to the early 1800s for a blueprint of an Austen-esque future where people sit around all day matchmaking and throwing high society balls? Appealing, but few of us would have the money for such extravagances – Mr Darcy was worth roughly £6m a year in today's money. Even Callendar, in his leisurely pursuit of climate change data, had the benefit of his steam engineer father's 22-room mansion and greenhouse laboratory. And matchmaking will probably be done by the robots, anyway – dating apps already use algorithms and machine learning to up our chances of finding a sweetheart.

4 We'd get money for nothing

In a work-scarce future, the gap between rich and poor is predicted to grow, as a small, tech-savvy elite occupies the few remaining high-paid jobs. A 2019 European Commission report on AI and work highlighted a risk to low-paid and routine jobs, which could "exacerbate inequality significantly". The report also explores the idea of a universal basic income to help bridge the divide. Although many versions exist, basic income schemes generally aim to provide people with a regular income to cover essential living costs. Some are totally unconditional, while others depend on meeting certain criteria. Ongoing basic income trials exist, such as a 12-year-long Kenyan project across 120 villages, funded by a US charity. But as Dr Luke Martinelli, who studies basic income, explains, it's hard to design a realistic trial. "The Kenyan one is just giving people money," he says. "It doesn't consider the other side of the equation where [in the absence of charity funding] the state would have to claw back the money through the tax system." So in reality, such a scheme could end up being funded by any remaining well-paid workers, through higher tax rates.

The general consensus is that a basic income would provide only enough for a meagre living, meaning many of us would still be seeking part-time work. Martinelli describes it as a "boost" for the worst-off and, for others, a chance to pursue new kinds of work.

5
There'd probably still be housework

Imagined post-work futures don't usually take into account all of the unpaid domestic labour that forms a substantial part of our lives. Even if we have a liveable basic income, and a sense of purpose from some kind of community endeavour, we'll still have the washing up to do and the kids to put to bed.

According to Dr Helen Hester, technofeminism researcher and author of the upcoming book *After Work: The Fight For Free Time*, the machines we've introduced to the household so far have provided only limited relief. This is because we spend any time our household appliances save us on deeper cleaning and increasingly engaging activities for our children. A 2016 study by Oxford University researchers, for example, showed that in the US, a woman with one child does about two fewer hours of cooking and cleaning a day than she did in the 1920s, but an hour or more of this is reabsorbed into childcare. So it's likely that, whatever household robots we employ, we'll still end up carrying out some domestic tasks.

Hester thinks that we could be more open to automating care work at home – for example, using care robots to help us look after children and elderly parents. But she says there's a "moral value" attached to doing this work ourselves that often leads to us "dismissing automation out of hand". So perhaps the greatest hurdle to having more robots in our homes is not technological, but our own reservations about handing the work over to machines. **SF**

by **HAYLEY BENNETT**
(@gingerbreadlady)
Hayley is a freelance science writer and editor, working (without robots) in Bristol.

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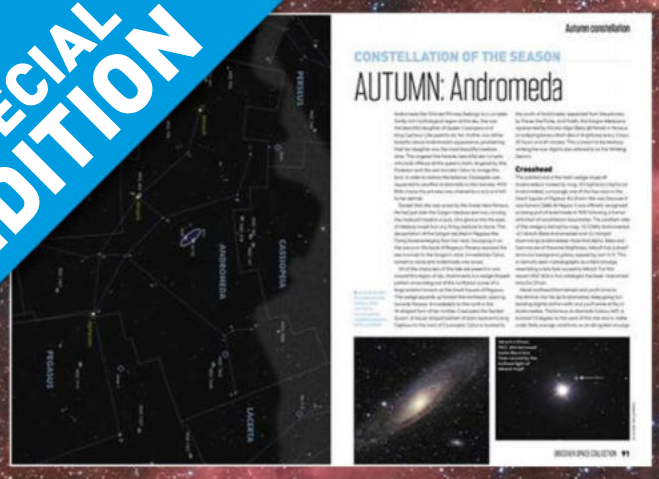

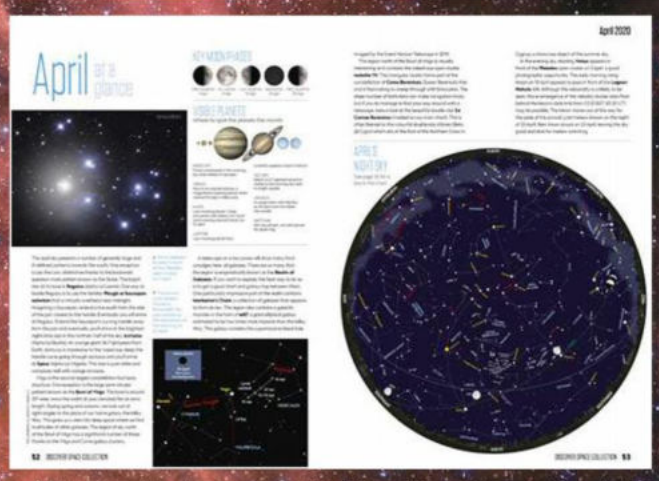

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Q&A

ALL YOUR QUESTIONS ANSWERED

THIS ISSUE'S EXPERTS

DR STEVE BRUSATTE
Palaeontologist, dinosaur expert

ALEX FRANKLIN-CHEUNG
Environment/ climate expert

ALOM SHAHA
Science teacher, author

PROF ALICE GREGORY
Psychologist, sleep expert

DR HILARY GUITE
Former GP, science writer

CHARLOTTE CORNEY
Zoo director, conservationist

DR HELEN SCALES
Oceans expert, science writer

DR CHRISTIAN JARRETT
Neuroscientist, science writer

DR EMMA DAVIES
Chemistry expert, science writer

LUIS VILLAZON
Science/tech writer

JULES HOWARD
Zoologist, science writer

PROF ROBERT MATTHEWS
Physicist, science writer

GETTY IMAGES

JAKE EDWARDS, LIVERPOOL

WHY DO BODYBUILDERS OFTEN GET PROTRUDING VEINS?

Prominent veins – known as 'vascularity' – is an aesthetic that's prized by many bodybuilders, but it has nothing to do with muscle size. Most of the effect is down to the dramatic reduction in subcutaneous fat, which makes the skin appear paper-thin and almost transparent. Just before a competition, many bodybuilders also dehydrate themselves to shrink the tissues just under the skin, making the veins pop out even more. *LV*

LUC WALLACE, CANTERBURY

ARE BABIES BORN WITH A SENSE OF RIGHT AND WRONG?

Early theorists in psychology mainly took the approach that babies are born without any sense of morality and have to learn it as they get older. We now know that although a fully developed sense of morality does not emerge until adolescence or later, babies already show signs of a rudimentary moral compass.

Consider a 2010 study by researchers at Yale University that involved babies as young as three months old watching a live 'show' of different shaped wooden blocks on a hill (the shapes corresponded to different characters, who either helped or hindered another character who was struggling to get up the hill). The researchers found that the babies preferred looking at the helpful characters, suggesting early preference for altruistic social behaviour. Similar research with five-month-olds has shown that they have a sense of 'justified retribution': they prefer characters who hinder a previously obstructive individual rather than help them.

A sense of fairness also emerges early. In a study last year by researchers at the University of Washington, 13-month-old babies watched a researcher who distributed crackers fairly or unfairly among two other adults. When the infants were given a chance to interact with the researcher, they were more inclined to interact with a fair researcher than an unfair one, indicating that they had a preference for fairness.

Finally, a cute line of research has looked at babies' inclination to respond to the needs of others, showing that already by age one they will offer comfort to a person who has hurt themselves, or try to help someone obtain an item that's out of reach. The spontaneity of these behaviours has led scientists to believe that a sense of right and wrong is not entirely learned, but rather indicative of an evolved predisposition towards moral goodness. ***CJ***

JAY COLLINS, STROUD

WHY ARE CELESTIAL OBJECTS NAMED AFTER GREEK AND ROMAN DEITIES?

The planets from Mercury to Saturn are all visible with the naked eye, and so have been known since antiquity. These were all named by the Ancient Greeks, and we have kept those names, or their Roman versions. Uranus is also visible without a telescope, but it moves so slowly across the sky that it was mistaken for a star until William Herschel proved it was a planet in 1781. He initially planned to name it Georgium Sidus (George's Star) after King George III, but this was unpopular outside Britain, and astronomers eventually settled on Uranus (the Greek god of the sky) to stick with the mythological theme. Nowadays, the International Astronomical Union decides on the naming rules, but they aren't all Greek or Roman. Dwarf planets Haumea and Makemake are Polynesian deities, for example. *LV*

ADAM KING, HUDDERSFIELD

IF THE SUN IS CONSTANTLY LOSING MASS VIA NUCLEAR FUSION, HOW COME IT'S NOT GETTING ANY SMALLER?

The Sun gets its energy by crushing together hydrogen and other atoms until they fuse together. By Einstein's famous equation $E = mc^2$, this energy output leads to a loss in the Sun's mass of over 350 billion tonnes each day. That sounds a lot, but it's dwarfed by the Sun's total mass of two billion billion billion tonnes. And in any case, for most of its life the Sun more or less maintains its size by balancing the inward-acting force of gravity against the outward pressure caused by its nuclear fusion reactions. But over billions of years, the Sun will burn through so much of its fuel that this balancing act can no longer be sustained. Changes in the Sun's internal composition will lead to the outward pressure getting so strong that the Sun's gravity will no longer resist it – and the Sun will begin to expand. Eventually it will become a colossal red giant star, ballooning out almost as far as the Earth's orbit. *RM*

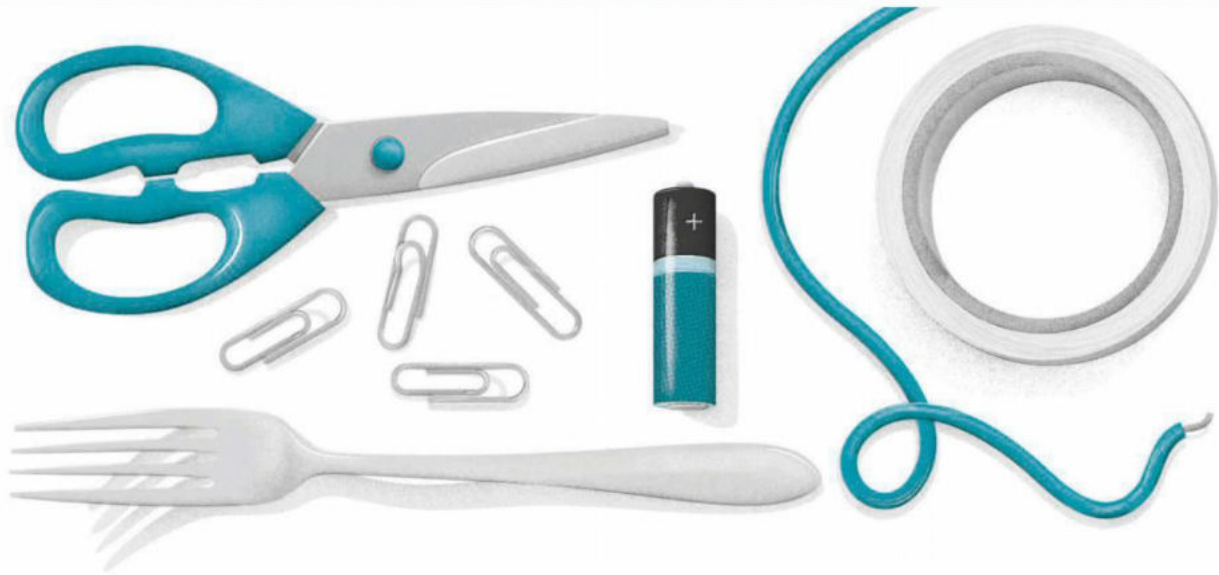
DIY SCIENCE

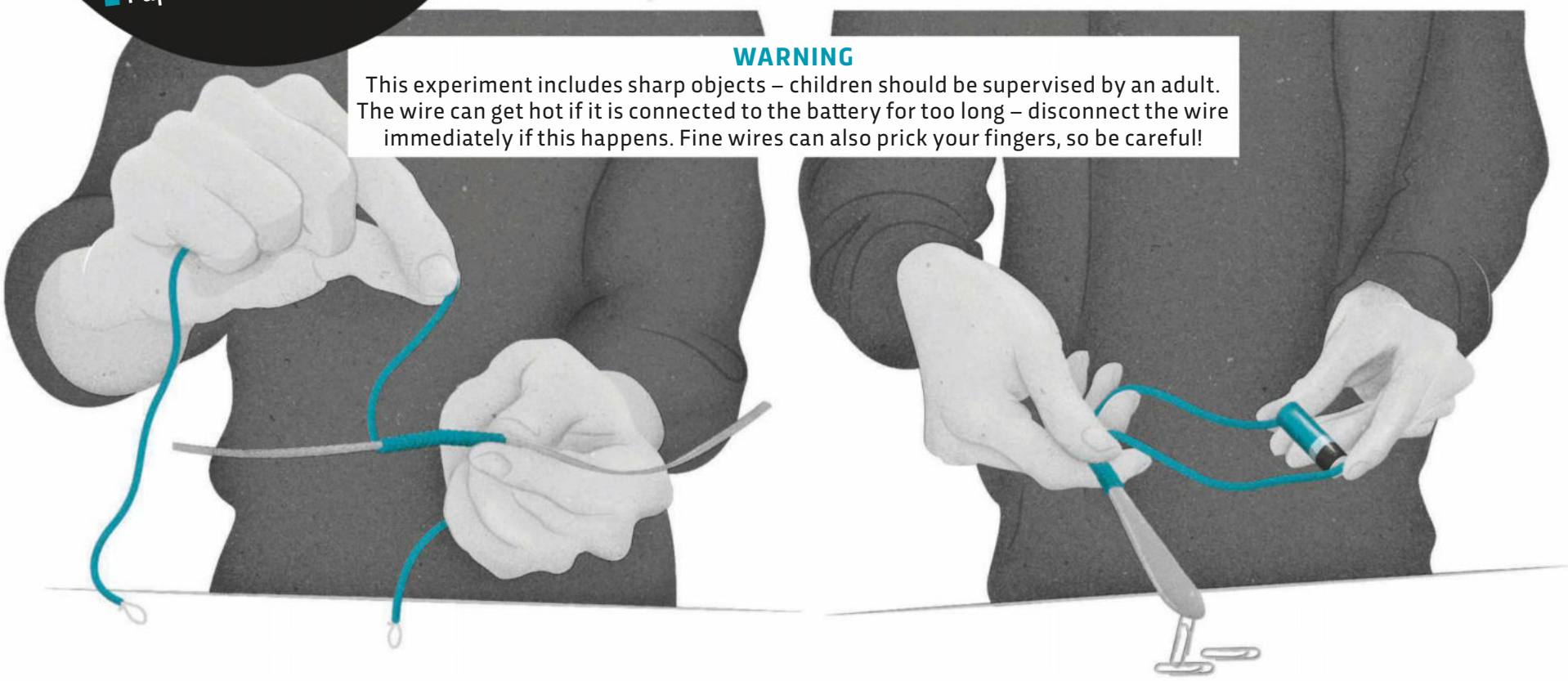
SIMPLE ELECTROMAGNET

We'd love to see pictures of your experiments. Send them to us on Facebook or Twitter (**@sciencefocus**) and we'll share our favourites!

WHAT YOU'LL NEED

- About one metre of insulated wire (you can get this from an unused power cable or phone charger)
- Wire stripper or scissors
- Stainless steel dessert spoon or fork
- Sticky tape
- Battery (size AA, AAA or C will work)
- Paperclips (or drawing pins)





WARNING

This experiment includes sharp objects – children should be supervised by an adult. The wire can get hot if it is connected to the battery for too long – disconnect the wire immediately if this happens. Fine wires can also prick your fingers, so be careful!

WHAT TO DO

1. Strip about 2cm of the insulation off both ends of the wire using a wire stripper or scissors.

2. Twist each uninsulated end of the wire firmly to bring together any loose fine wires, making a thick braid of wire. Fold this in half and twist it into a flat loop at each end (this will make it easier to get a good contact with the battery terminals).

3. Starting about 10cm from one end of the wire, coil the wire tightly around the handle of your spoon or fork. Do not overlap the coils, and leave about 10cm of uncoiled wire at the other end.

4. Wrap sticky tape around the coils of wire to hold them in place.

5. Using the thumb and finger of one hand, press each end of the wire against opposite ends of the battery.

6. Using your other hand, hold the spoon or fork and use it to magnetically pick up paperclips or drawing pins.

WHAT'S HAPPENING

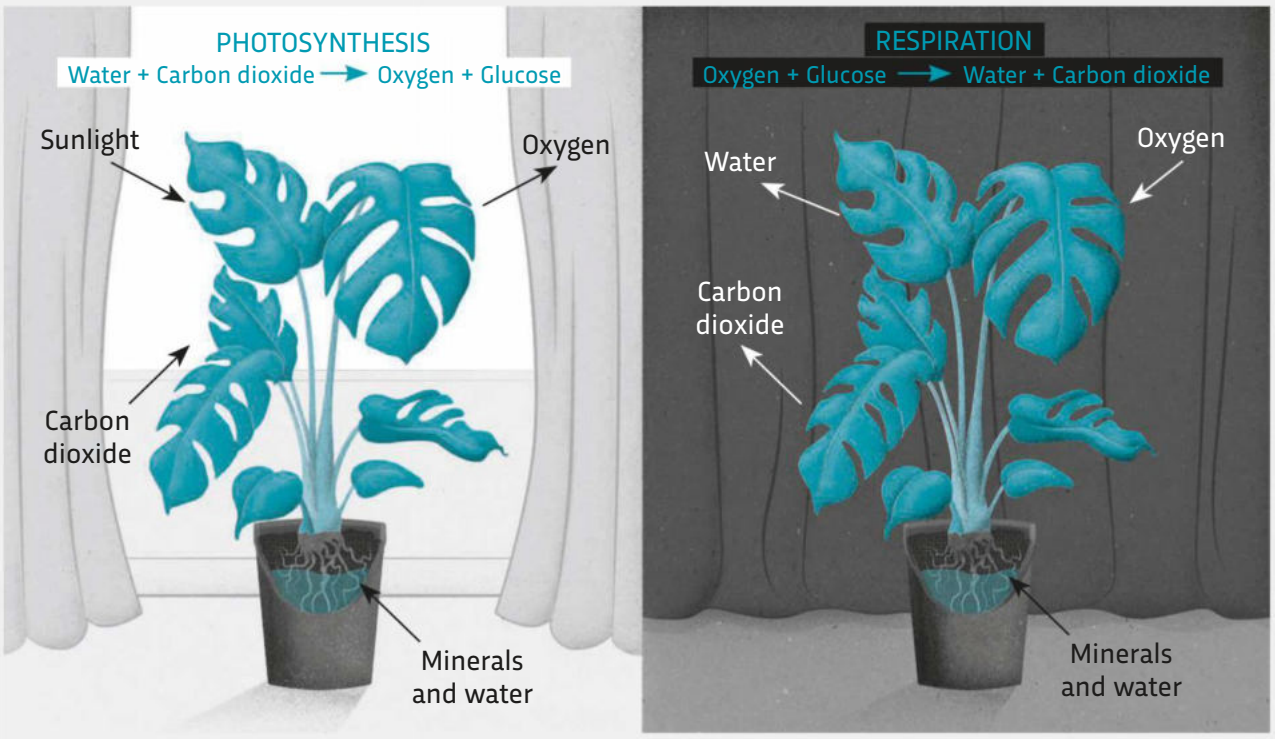
Electromagnets are a particular type of magnet that only work when an electric current is passed through them.

They rely on the fact that a movement of charged particles (in this case, electrons) creates a magnetic field. In fact, *all* magnetic fields arise from the movement of charge. Most objects are non-magnetic because the individual magnetic fields of the electrons moving around inside them are randomly aligned and cancel each other out.

When you connect the wire to the battery, electrons begin to flow in the same direction through the wire, and this generates a magnetic field around the wire. By coiling the wire around a stainless steel core, you're creating a combined magnetic field in the wire and core, which is strong enough to pick up objects.

Electromagnets are useful because their magnetic fields can easily be controlled: the greater the current, the stronger the magnetic field. Increasing the number of coils also increases the magnetic field. This activity demonstrates that electricity and magnetism are essentially two aspects of the same phenomenon, called 'electromagnetism'. ***AS***

GETTY IMAGES X2 ILLUSTRATION: DAN BRIGHT



JESSICA LEES, IPSWICH

IS IT TRUE THAT YOU SHOULDN'T KEEP PLANTS IN THE BEDROOM?

Some people worry that plants in the bedroom will cause carbon dioxide (CO_2) poisoning, but this is an urban myth. It's true that when you turn off the light, the plant no longer has a source of energy, and so photosynthesis stops. This means that it no longer takes in CO_2. Meanwhile, in the dark, the plant continues to respire – a process which releases CO_2 (the exact quantity of which depends on the size of your plant and its species). However, any plant small enough to fit in your bedroom produces far less carbon dioxide than a sleeping human, and is perfectly safe to share a room with. ***AFC***

CHRIS ANDREWS, SALISBURY

DO DIMMER SWITCHES ACTUALLY USE LESS ENERGY?

As electricity is often portrayed as a stream of energy, it's tempting to think of dimmer switches like dams that only let some of the electricity through, with the rest leaking out as heat elsewhere – and so not really saving energy at all. In fact, modern dimmer switches work by using circuitry that rapidly turns the electricity to the lights completely on or off, with the switching rate determining the brightness. As such, dimmer switches really do save energy. ***RM***

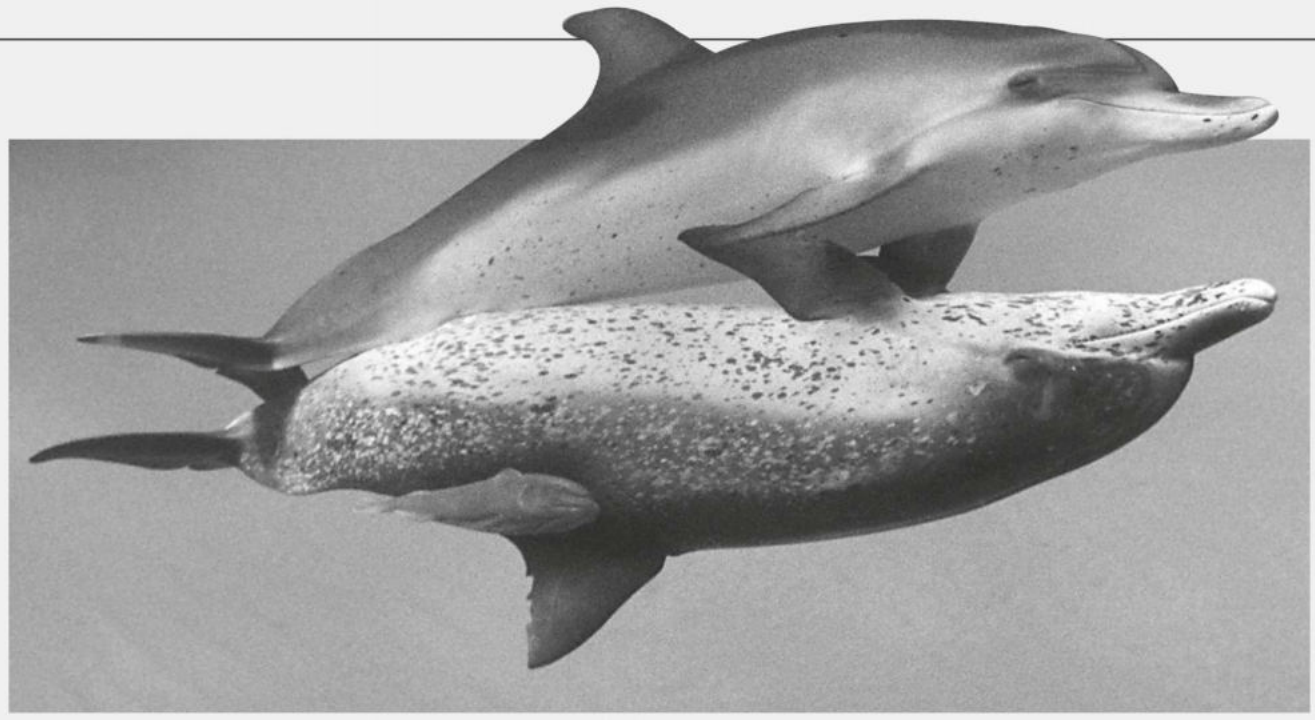
NATURE'S WEIRDEST CREATURES...

THE SCALY-FOOT SNAIL

Earlier this year, the scaly-foot snail became the first species to be listed as endangered due to the threat of deep-sea mining. This marine mollusc might not have the charisma of the orangutans and pandas of this world, but a closer look reveals that it's just as special.

First off, this is a small animal with a big heart – approximately 4 per cent of its body volume, to be precise. This makes it the largest heart – relative to body size – in the entire animal kingdom, helping the snail to live in an environment that's largely devoid of oxygen. So far, the snail has been found in only three locations – all hydrothermal vents in the Indian Ocean, as much as three kilometres below the surface. These vents provide food for the snail, via a farm of microbes (called 'chemoautotrophs') that it keeps in a special pocket in its gut. The microbes break down the chemicals that leak from the volcanic vents, creating food in the process.

The scaly-foot snail is the only organism known to incorporate metals (in the form of iron sulphides) into its 'skeleton', both into its shell, and into the hundreds of external scales which give it its name. It's the RoboCop of the ocean world, but this unique armour will provide little defence against the mining projects that threaten its deep-sea habitat. ***JH***



BILL STRUDWICK, VIA EMAIL

DO ANY OTHER ANIMALS HAVE SEX FOR PLEASURE?

The primary function of sex is to reproduce, so it would make sense that nature would incentivise animals to mate by rewarding them with a pleasurable experience. We don't know how many animals experience sexual pleasure, but we have evidence for it in a number of species. Bonobos and other primates will have sex while pregnant or lactating – seemingly just for the joy of it – while short-nosed fruit bats engage in oral sex to prolong their bouts of intercourse (there might be evolutionary reasons for this, but it could also be for fun). Meanwhile, the clitorises of female dolphins possess nerve bundles, erectile tissue and blood vessels, which could enable them to climax, and female Japanese macaques have been observed orgasming – despite there being no direct reproductive benefit of this. ***CC***

JACOB MASLEN, SALISBURY

WHAT MAKES SUGAR SWEET?

The sweetness of sugar comes from a chemical interaction between sugar molecules and sweet taste receptor cells, which are found in our taste buds and on the roof of our mouth. Sugar molecules are festooned with oxygen-hydrogen pairs called hydroxyl groups, and these lock into the receptors using an electrostatic attraction known as 'hydrogen bonding'. As soon as this happens, a chain of molecular events sends nerve signals to the brain, which interprets these signals and gives us the perception of sweetness. ***ED***

KELLY LAWRENCE, DERBY

HOW DOES BUBBLE BATH WORK?

A running bath naturally creates air bubbles, but these pop quickly as they're pulled back into the main body of water by the high tension at the water's surface (this 'surface tension' results from the attractive forces between water molecules). Bubble bath contains chemicals called 'surfactants' that weaken the attraction between the water molecules and lower the surface tension, meaning that the bubbles can last for longer. The surfactants also increase the bubbles' elasticity, which makes them more resilient to being squeezed and deformed. As the bubbles grow in number, your bath becomes a frothy delight. ***ED***

OLD WIVES' TALES...

YOU WON'T FEEL THE BENEFIT IF YOU WEAR YOUR COAT BEFORE GOING OUTDOORS

There's a degree of truth to this. Provided you aren't ill, your body regulates your *core* temperature to between 36.5°C and 37.5°C. But your *skin* temperature is more variable, and results from a balance between how fast you generate heat from your core, and how quickly you lose heat to your surroundings. If you keep your coat on indoors, it makes it harder for your body to shed heat from your core, so warm blood is pumped from your core to your skin to compensate, and your skin temperature rises.

The temperature that you *perceive* when you step outside depends on the difference between the temperature of your surroundings, and the temperature of the exposed skin on your hands and face. So since your skin is already toasty from wearing your coat indoors, it'll feel colder against the cold air, you'll lose heat faster, and it'll take a minute or two before your body reacts and diverts the blood back to your core. The benefit of taking your coat off indoors, then, is that you step outside with a lower initial skin temperature, and it doesn't take as long for your body to acclimatise to the temperature difference. Plus, you can put your coat on to reduce any additional heat loss. *LV*

GETTY IMAGES X4, IUCN ILLUSTRATION: DAN BRIGHT

DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I CAN'T STOP CHECKING MY PHONE. WHAT CAN I DO TO LESSEN ITS GRIP ON ME?

There are some simple practical steps you can take: switch off as many automatic notifications as you can (the less your phone is pinging and vibrating in your pocket, the less inclined you'll be to check it), and set yourself some boundaries, such as not taking your phone in the bedroom or having it to hand at mealtimes. Banning yourself from checking your phone altogether is unlikely to work long-term. Instead, get more control by planning specified times when you're allowed to indulge in some news browsing or social media bingeing.

At a deeper level, consider the psychological need(s) that your phone-checking is satisfying. As with beating any unwelcome habit, you're more likely to succeed if you can replace the habit with a healthier alternative. For instance, if boredom is the issue, consider carrying an entertaining book or magazine that you can glance at instead. Alternatively, perhaps you're really craving more social interaction – if so, consider finding ways to increase your opportunities for more face-to-face contact, such as by joining a sports club or volunteering for charity. ***CJ***

MY BOYFRIEND IS LIKE A HUMAN WOOKIEE. WHY ARE SOME GUYS SO HAIRY?

Like so many things, it comes down to a mixture of genetics and hormones. We know that at least some of the genes for hairiness are carried on the X chromosome – and the way these genes are expressed varies between different men and ethnic groups – but hairiness also correlates with high testosterone levels. Male hairiness may in fact have evolved as a way of signalling testosterone levels to potential mates, because testosterone also makes men develop more muscle. So it's possible that your boyfriend's hairiness was one of the things that attracted you to him, as you subconsciously sought out a partner who could take down a woolly mammoth. ***LV***

MY PREGNANT WIFE WANTS TO EAT HER PLACENTA. SHOULD I BE WORRIED?

A small number of women do choose to eat their own placentas after giving birth. This practice of 'placentophagy' is often in the news, with celebrities claiming that the high levels of nutrients, proteins and hormones in the organ can increase bonding and milk production, lessen fatigue and improve mood. But research has found no definitive evidence for any of these effects.

There are also risks: a fresh placenta whizzed up as a smoothie with some berries could contain toxic metals such as cadmium, lead and mercury, as well as harmful bacteria – one study found *E. coli*. Even steamed and desiccated placenta tablets (the most common way to eat your own placenta) are not completely sterile.

Don't be too worried, though: the risks are small. Most important is to provide practical, social and emotional support so that hopefully your wife doesn't feel the need to take a punt on something that has no proven benefits. ***HG***

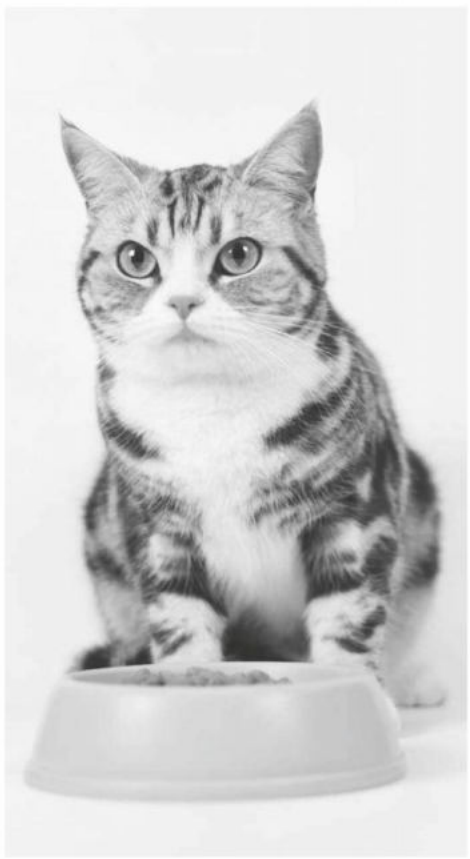
STUART ROBB, LUTON

DOES SOUND TRAVEL FURTHER ON FOGGY DAYS?

Sound travels through the air as pressure waves rhythmically moving air molecules back and forth. Fog contains water droplets that scatter more of the sound energy, thus damping the sound and reducing the distance at which you can hear it. All very simple – and confirmed by laboratory experiments. So, case closed? Not quite – because both the basic theory and experiment don't take account of all the conditions under which fog forms. On warmer days where the humidity is especially high, the water molecules in the air are more agitated and can only form the tiniest droplets, which have a negligible effect on the sound waves. This damp air also has a higher density than dry air, which means that the sound waves can travel more effectively and be heard over a greater distance. ***RM***

REX LEGGE, VIA EMAIL

ARE OUR PETS BAD FOR THE ENVIRONMENT?



In a word, yes. The biggest environmental impact associated with our animal companions comes from producing meat-based pet food, which uses land, water and energy resources, and is a significant source of greenhouse gas emissions. According to one estimate, owning a medium-size dog can have a similar carbon footprint to a large SUV. Plant- and grain-eating pets such as rabbits and rodents have a much smaller impact. As well as food, pets need toys, grooming products and various accessories, which also come at an environmental cost. To reduce the strain on the environment, buy only the food that they need, and have your pet spayed or neutered to reduce the chance of unwanted litters, which can lead to overpopulation in rescue shelters.

Finally, some cat owners worry about the wild animals killed by their moggy. But while UK cats are estimated to kill up to 300 million prey a year – mostly small mammals and birds – there's no clear evidence that this causes a decline in wild populations. ***AFC***

ELIZABETH SPRASON, STOURBRIDGE

COULD I SURVIVE JUST ON DIFFERENT FLAVOURS OF ICE CREAM?

The main ingredients of ice cream are milk, cream, sugar and eggs. A plain vanilla flavour has about 200 kilocalories (kcal) per 100g, so you would need to eat about a kilo of it per day to get enough calories. This would only give you about 30g of protein per day, which is a little low, but milk and eggs do contain all the essential amino acids your body needs. Eggs and milk also contain vitamins A and D, and most of the B vitamins, and you could take care of the rest with different ice cream flavours. Premium brands that include real fruit puree and nuts, instead of just flavour extracts, should give you enough vitamin C and E.

The downside is that an ice cream-only diet would give you way too much saturated fat and sugar, increasing your risk of coronary heart disease and diabetes. So while you may be able to survive, it's not a recommended dietary strategy! ***LV***

20

The number of additional moons of Saturn that have been spotted by a team at the Subaru Telescope in Hawaii. This means that Saturn has 82 discovered moons – more than any other planet in the Solar System.

HIDDEN FIGURES

MARY ANNING
FOSSIL HUNTER EXTRAORDINAIRE

Between Swanage in Dorset and Exmouth in Devon lies the Jurassic Coast, world-renowned as the site of fossils that have transformed our understanding of life on Earth. But in the early 1800s, the fossils were regarded largely as curiosities, sold to tourists as souvenirs. Among those who collected them was Mary Anning, whose discoveries helped reveal their true significance.

Born in Lyme Regis, Dorset in 1799, Anning helped her family boost their meagre income by selling fossils she found in local limestone cliffs. At the age of 12, she and her older brother made a spectacular find: the complete skull and torso of an ichthyosaur – a large marine reptile. Then in 1823, she found the first complete skeleton of a plesiosaur, another ancient marine reptile.

Distinguished geologists started to work with her, among them William Buckland of Oxford University. He was intrigued by Anning's discovery that stony objects found near ichthyosaur skeletons contained fish bones, suggesting that they were fossilised faeces. In 1829 he announced that she was right, and that such 'coprolites' gave insights into the diet and behaviour of long-extinct creatures.

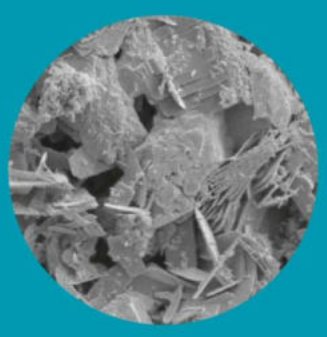
Barred by her gender from joining the Victorian scientific establishment, in 2010 Anning was named by the Royal Society as one of the 10 most influential British women in science history. *RM*

GETTY IMAGES X4 ILLUSTRATIONS: DAN BRIGHT

WHAT CONNECTS MOUNT VESUVIUS AND CARROTS?

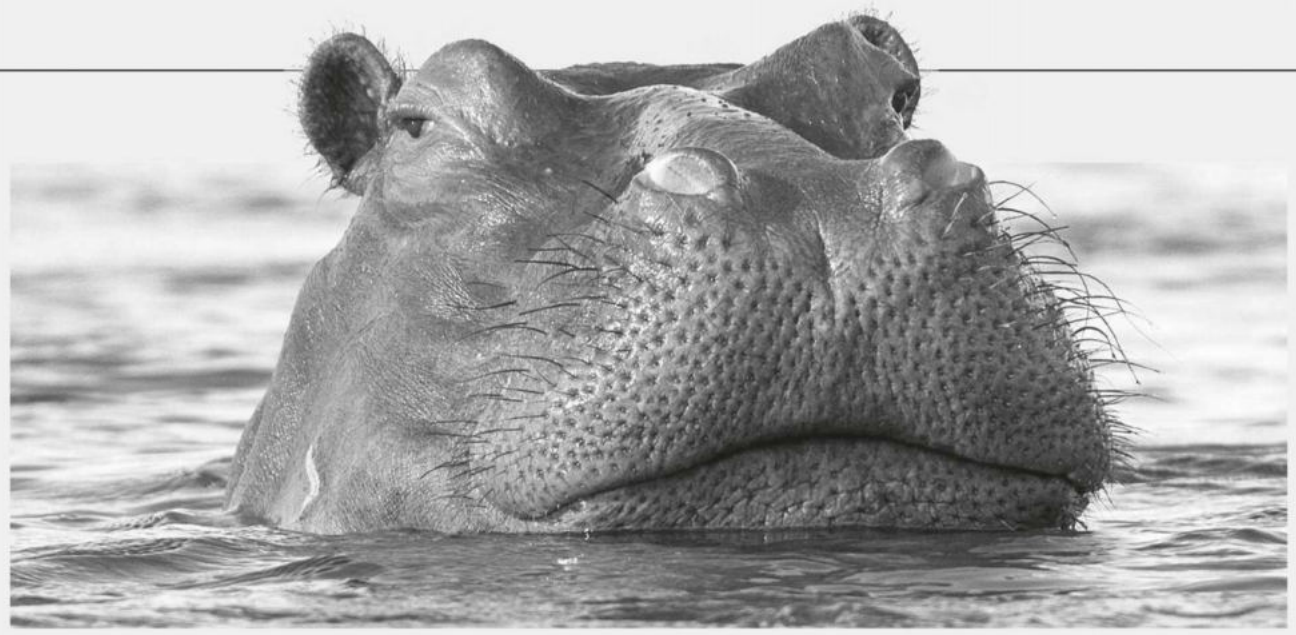
1. Mount Vesuvius, in southern Italy, is the most active volcano in mainland Europe. It has erupted 12 times in the last 200 years, most recently in 1944.

2. Ash from Vesuvius was used in Ancient Rome to make incredibly strong concrete. Concrete piers from Roman harbours, dating back 2,000 years, are still standing, while modern marine concrete can corrode within decades.



3. The strength of Roman concrete comes from aluminium and silica minerals in the ash that crystallise as seawater seeps into microscopic cracks. This helps bind the concrete and prevent larger cracks forming.

4. Nanoparticles of cellulose, taken from root vegetables like carrots, can perform even better. Lancaster University researchers found that carrot-reinforced concrete was more than twice as strong as standard concrete.



BRIAN KIRKBY, VIA EMAIL

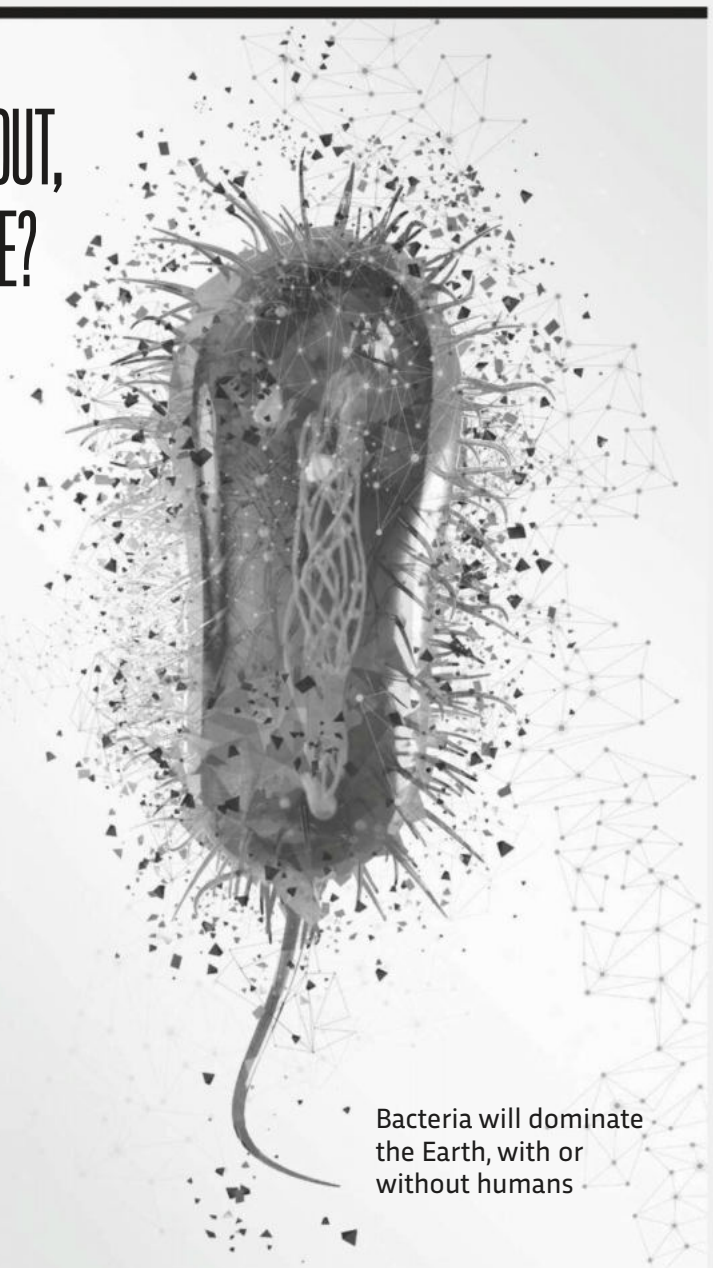
IF YOU DROPPED A HIPPOPOTAMUS OFF THE SIDE OF A SHIP, WOULD IT SINK TO THE BOTTOM OF THE OCEAN?

Despite their semi-aquatic existence, hippos are actually not great swimmers. They don't have streamlined bodies or flippers, and although their toes are webbed, their legs are rather short and fat. Instead, they mostly move with a sort of slow-motion gallop along the riverbed. In order for this to work, they have to be denser than water. Most mammals are naturally buoyant, but hippos have especially dense bones to help them stay on the bottom. Seawater is about 2.5 per cent denser than fresh water, but the extra buoyancy this provides isn't enough to offset the weight of a hippo, and it will still sink in the sea. And because the buoyancy is always equal to the weight of the volume of water that the hippo displaces, it remains the same regardless of depth. So once the hippo starts sinking, it's doomed to make a one-way trip to the ocean floor. ***LV***

PAUL FARNHAM-SMITH, FOLKESTONE

IF THE HUMAN RACE WAS WIPED OUT, WHICH SPECIES WOULD DOMINATE?

Humans have certainly had a profound effect on their environment, but our current claim to dominance is based on criteria that we have chosen ourselves. Ants outnumber us, trees outlive us, fungi outweigh us. Bacteria win on all of these counts at once. They existed four billion years before us, and created the oxygen in the atmosphere. Collectively, bacteria outnumber us a thousand, billion, billion to one, and their total mass exceeds the combined mass of all animals. They have colonised the entire planet, from the stratosphere to the deepest ocean, and despite all our technology, antibiotic-resistant bacteria continue to kill hundreds of thousands of us every year. When humans are gone, other species may take our place, but bacteria will continue to dominate the planet. ***LV***



Bacteria will dominate the Earth, with or without humans

GETTY IMAGES X5, ALAMY, J P OLESON, MARIE JACKSON ILLUSTRATIONS: DAN BRIGHT

STEVE LAWER, VIA EMAIL

WHEN WE SMILE, WHY DO WE ONLY BARE OUR TEETH WHEN WE KNOW THE PERSON WELL?

When we're comfortable with someone, we'll tend to smile in a more genuine and spontaneous way. Smiling without showing our teeth is more of a forced smile. This is backed up by a 2009 Dutch study, in which men were filmed performing posed smiles and spontaneous smiles, with the latter provoked by watching a funny film. When the researchers compared the two types of smile, they found that genuine smiles were both wider and toothier than posed ones. ***CJ***

VANESSA FISHER, PLYMOUTH

DO OSTRICHES REALLY BURY THEIR HEAD IN THE SAND?

As flightless birds, ostriches are unable to build nests in trees, so they lay their eggs in holes dug in the ground. To make sure that the eggs are evenly heated, they occasionally stick their heads into the nest to rotate the eggs, which makes it look like they're trying to hide – hence the myth. An ostrich trying to hide from predators in this way wouldn't last for long, and it wouldn't be able to breathe, either! ***CC***

QUESTION OF THE MONTH

PETER MAKEPEACE, NORTHAMPTONSHIRE

WHAT WOULD DINOSAURS HAVE TASTED LIKE?

Dinosaurs probably would have tasted like chicken. Okay, so everybody always says that everything tastes like chicken. But I'm not being facetious. Birds evolved from dinosaurs, which means that they're essentially modern-day dinosaurs. Of course, not all birds taste like chicken, though. So maybe some dinosaurs would have tasted like duck or turkey or game birds, depending on the dinosaur's diet and fat content. Plant-eating dinosaurs such as *Triceratops* and *Diplodocus* probably would have been tastiest. The animal fat in the diet of carnivorous dinosaurs such as *Tyrannosaurus rex* and *Velociraptor* would have given them an overly 'gamey' flavour (one of the reasons we eat cows but not wolves). *SB*

WINNER

Peter wins a Yeti X USB microphone from Blue, RRP £159.99. This quality microphone boasts excellent sound, clarity and vocal effects, making it ideal for podcasting, gaming, live streaming, or simply chatting to friends online. **bluedesigns.com**

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RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH

Babies and baubles
Doctor-turned-writer Adam Kay tells us about a hospital Christmas p100

Chew over this
Liz Bonnin finds out what price the planet pays for our love of meat p102

Reading list
Our pick of the best books to hit the shelves this month p102

Books that made me
Psychologist and presenter Claudia Hammond reveals her favourite books p103

1

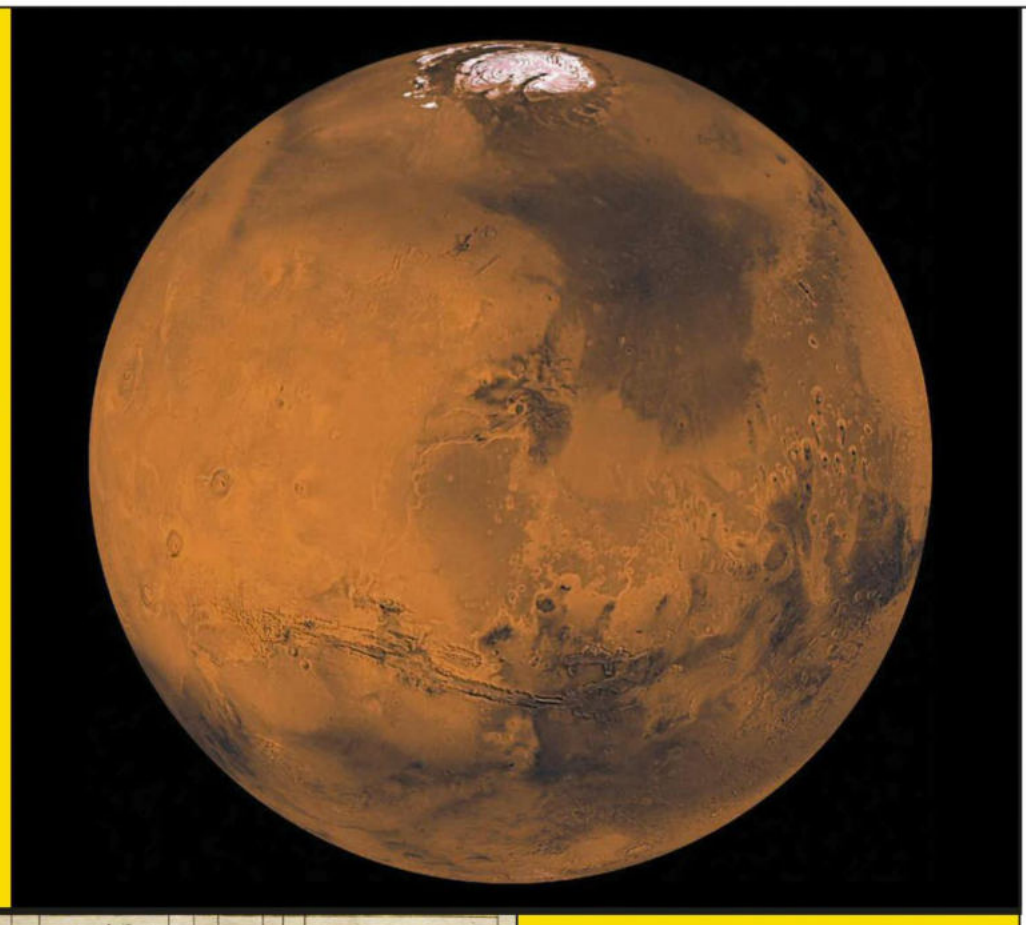
MOVING TO MARS

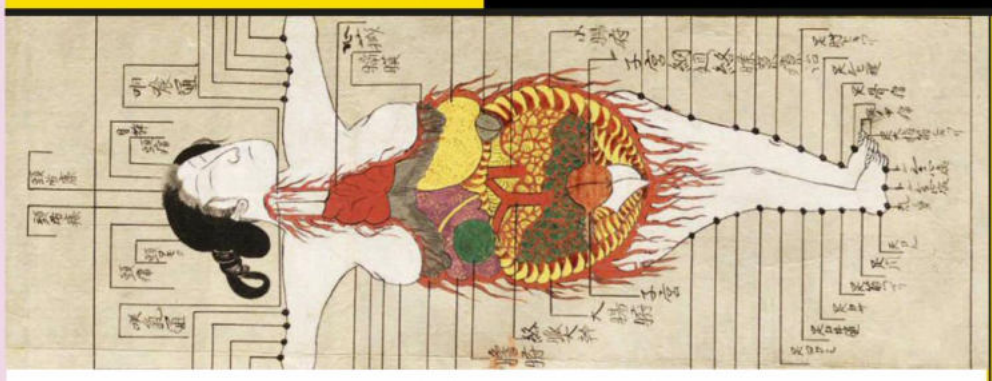
The Design Museum, London

Immerse yourself in Martian life without leaving London. Includes objects from NASA, ESA and SpaceX. Museum entry is free, extra charge for the exhibition.

Until 23 February

bit.ly/design_mars





2

UNDER THE SKIN: ANATOMY, ART AND IDENTITY

Royal College of Physicians, London

The science of anatomy has a controversial history, as mentioned at the end of 'Forbidden Medicine' (p79). This exhibition raises questions about consent and identity, and showcases the work of artists in the discussion of dissection. Free entry 9am-5pm, Monday to Friday.

Until 2 April

bit.ly/anatomy-art-identity

3

NATIONAL TREE WEEK

Celebrating the start of tree-planting season, National Tree Week events are held across the UK and include lectures, tree plantings and walks with expert rangers at certain National Trust sites.

23 November – 1 December

treecouncil.org.uk

4

PARASITES: BATTLE FOR SURVIVAL

National Museum Scotland, Edinburgh

This new exhibition reveals Scotland's role in the world's fight against five deadly tropical diseases. Malaria, guinea worm disease, sleeping sickness, schistosomiasis and leishmaniasis: together, these diseases affect 1 in 18 people around the world. Yet all but malaria have been classified as neglected and having a lack of funding and research. *Parasites* is an interactive exhibition showcasing the important work of teams at Scottish universities in identifying and treating these diseases.

From 6 December

nms.ac.uk/parasites

NASA, NATALIE SHAW, PAUL WILKINSON/ROYAL INSTITUTION, GETTY IMAGES X2, ROYAL COLLEGE OF PHYSICIANS

5

24/7: A WAKE-UP CALL FOR OUR NON-STOP WORLD

Somerset House, London

Stop, switch off, engage with the natural world and reflect on the pace at which we move through it. This new major exhibition explores our non-stop culture through interactive installations, storytelling and music.

Try out Tatsuo Miyajima's meditative isolation chamber or listen to an orchestra of engines in Alexandra Daisy Ginsberg's machine generated dawn chorus. Perhaps leave your phone in your pocket, though, for a truly unplugged experience. Adult tickets £14, under-12s free.

Until 23 February

somersethouse.org.uk

6

NINE LESSONS AND CAROLS FOR CURIOUS PEOPLE (ROBIN INCE SHOW)

The Lowry, Manchester; and Kings Place, London

An end of year tradition for many, Robin Ince's show celebrates curiosity, comedy and creativity with a bunch of big-name guests. This year's line-up includes stand-up mathematician Matt Parker, comedian Josie Long and physicist Helen Czerski. More guests will be announced closer to the time and, as with past shows, there's bound to be a few surprise appearances on the night. Ticket prices vary.

Various dates in November and December

7

BUMP ROLLER DISCO

We The Curious, Bristol

Regular visitors to Bristol during the holidays might expect the return of We The Curious's seasonal ice rink, but this year the science centre has announced it will instead host a roller disco. The running of the ice rink consumed huge amounts of energy, and since declaring a climate emergency earlier this year, We The Curious has opted for the greener (and probably safer for our fingers) option of roller skating.

Until 5 January

bumpclub.co.uk/events

8

CHRISTMAS LECTURES LIVE STREAM

For the first time, the filming of the *Royal Institution's Christmas Lectures* will be live streamed to 18 venues throughout the UK, from Inverness to Birmingham, Leeds to Swansea.

This year's lectures are given by mathematician Dr Hannah Fry, who will be revealing the hidden power of maths in everyday life.

12, 14 and 17 December

bit.ly/xmas-lectures-venues

Profile

BABIES AND BAUBLES

ADAM KAY, BESTSELLING AUTHOR OF *THIS IS GOING TO HURT*, TALKS TO US ABOUT HIS NEW BOOK, WHICH REVEALS THE REALITY OF WORKING AS A DOCTOR IN AN NHS HOSPITAL OVER CHRISTMAS

YOUR FIRST BOOK, *THIS IS GOING TO HURT*, FEATURED DIARY ENTRIES FROM YOUR JOB AS AN NHS JUNIOR DOCTOR. WHY DIDN'T THESE FESTIVE STORIES MAKE IT INTO THAT BOOK?

I kept a lot more diaries than the ones that made it into *This Is Going To Hurt*. I tried to publish a fair selection of what it means to be a junior doctor: the funny stories, the sad stories, the mundane and the high octane, the bureaucracy… The vast majority of my stories were entirely unsuitable – a lot of it was too disgusting and some of it involved celebrities, and obviously for legal reasons they didn't go in. Many were Christmassy, because of the seven Christmases I was qualified, I worked for six of them. My editor pointed out that the book would be weirdly Christmassy if there were that many festive stories. So, there are a couple of Christmas stories in my first book, but a lot of them disappeared. I'm glad they did, because I managed to get a second book out of it.

DID YOU MIND WORKING OVER CHRISTMAS?

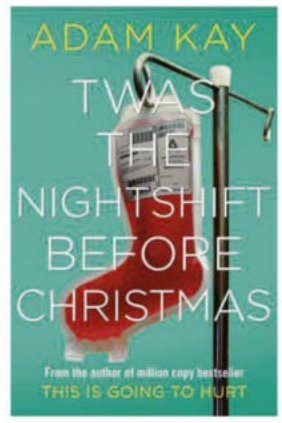
It ends up just being your normal. Missing Christmas is one piece of a slightly depressing jigsaw by which medicine takes a bit of a toll on your life. But it's the job you signed up for, and you accept it.

"Babies don't have a calendar, they don't care whether it's 25 December or 25 March"

YOU WORKED IN OBSTETRICS AND GYNAECOLOGY. DOES ANYTHING DIFFERENT HAPPEN IN THAT DEPARTMENT DURING THE FESTIVE SEASON?

There are no more babies born at Christmas than at other times of year. Babies don't have a calendar, they don't particularly care whether it's 25 December or 25 March.

Other parts of the hospital get a lot busier. We all know about the winter health crisis. There are more bugs going around and there's more ice on the ground so everyone can clatter to the floor and break their bones.



TWAS THE NIGHTSHIFT BEFORE CHRISTMAS
ADAM KAY
(£9.99, PAN MACMILLAN)

But one thing that is different is that people's spirits are a lot higher. I didn't hate working at Christmas. I'd have rather spent it at home, but it is quite fun being there [in the hospital] over Christmas.

WHAT'S THE ATMOSPHERE LIKE ON CHRISTMAS DAY?

It's often jolly and there's a lot more food on the ward, and the radio's blasting out Slade. It can feel like a kind of home-from-home atmosphere. It can be so busy that you don't even notice it's Christmas. But at the same time, when things do go wrong – and it's a hospital, so they do – the tragedy's sort of magnified against this backdrop of jollity.

WHAT THINGS WOULD YOU ADVISE PEOPLE TO AVOID DOING, OR BE AWARE OF AT CHRISTMAS TIME, TO PREVENT A VISIT TO A&E?

Most of the things that I saw were unpreventable, like going into labour. It's actually much more important to remember to seek medical attention. Don't put things off because you're worried there won't be the doctors there, or even worse, because you don't want to 'bother' the hospital. That's what they're there for.

The same rules apply if you have any worrying symptoms. Don't wait for it to settle down until after Boxing Day. Do still go in if you need to.

The one thing that everyone can do, obviously, is stop sticking stuff inside yourself. I know you've got a week off, so you have a lot more time on your hands and there's a lot of alcohol sloshing around, but that is an unnecessary use of NHS time. It does make for good anecdotes, and hopefully the occasionally funny entry in a book.

YOUR FIRST BOOK ENDED IN TRAGEDY, WHICH LED TO YOU LEAVING MEDICINE. WOULD YOU EVER BE TEMPTED TO GO BACK?

I think about this a lot. I chose a specialty in obstetrics and gynaecology, which meant that the bad days were too tough for me to deal with. The height of the highs – the highs are delivering babies, so you ended up with twice the number of patients you started with, which is a great batting average in any medical specialty – are set off with the depth of the lows. All you ever want is a healthy mum and a healthy baby, and that's not always the case.

I think I would be making a mistake if I went back onto labour ward. That said, I do really miss it. I miss the reason that I went into the job in the first place, which was to help people. Since my first book came out, I'm aware that I've been able to make a bit of a difference on the outside, but I know I could do more. When the writing's calmed down a bit and I'm no longer 'flavour of the month'… obviously, I do want to go back. I don't know if it's in terms of policy, or in terms of teaching medical students or junior doctors, but I do miss it, and I do want to do something. But I've probably done my last caesarean.

WHAT WOULD YOU SAY TO THOSE CONSIDERING ENTERING THE MEDICAL PROFESSION

I say that it's the most wonderful job in the world, and it's the most rewarding job in the world, and there's honestly nothing like it.

But I also say that it's job to go into with both of your eyes wide open. I get the occasional email from someone saying, "My child was going to do medicine and they read your book and now they don't want to."

The reply to that is, "Good, because if you're going to be put off by that book, you will definitely be put off by the actual job."

I think that my book should be a set text for people who want to do medicine, and not just for financial reasons, but because you do need to know what you're getting into.

ADAM KAY *(@amateuradam)*
Adam is an ex-NHS doctor, screenwriter, author and comedian. His first book, This Is Going To Hurt, *has won multiple awards and sold over a million copies.* Twas The Nightshift Before Christmas, *Adam's collection of festive diary entries, is out now.*
Interviewed by **BBC Science Focus** ***editorial assistant Amy Barrett.***

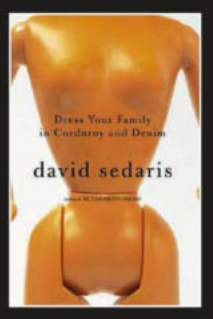
DISCOVER MORE

Subscribe to the Science Focus Podcast *and listen to our full interview with Adam in an upcoming episode.*
sciencefocus.com/science-focus-podcast

In this episode of All In The Mind, *Adam Kay and occupational health psychologist Prof Gail Kinman discuss workplace stress.*
bit.ly/mind_workplace_stress

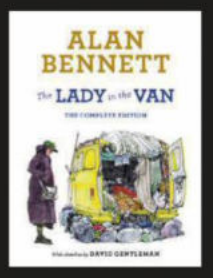
AUTHOR'S BOOKSHELF

I'm basically a low-rent David Sedaris and Alan Bennett tribute act. I would love to be able to write like them.



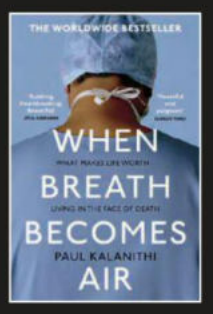
DRESS YOUR FAMILY IN CORDUROY AND DENIM
DAVID SEDARIS
(£9.99, LITTLE, BROWN BOOK GROUP)

For an entry-level David Sedaris book, go for *Dress Your Family In Corduroy And Denim*. It's just a wonderful collection of essays.



THE LADY IN THE VAN
ALAN BENNETT
(£6.99,PROFILE BOOKS)

A lot of people have seen the film of *The Lady In The Van*, but the book was the first thing I read of his, and I've since read every word he's written.



WHEN BREATH BECOMES AIR
PAUL KALANITHI
(£8.99, VINTAGE PUBLISHING)

I've definitely not invented the genre of medical writing. I think this is the most wonderful, powerful book in that genre.

ALAMY

RECOMMENDED

WHAT'S CAUGHT OUR ATTENTION THIS MONTH

by ***Amy Barrett***
EDITORIAL ASSISTANT

In the Bible, the three kings that brought presents to the baby Jesus were Babylonian astronomers. Like them, I too will be looking to the skies this month. I am hoping to see not the star of Bethlehem, but the ***Geminids meteor shower***. Taking place every year, the Geminids is one of the best annual showers and should peak for us on 14 December. The Moon is expected to be full and bright that night, so it might hinder your ability to spot the meteors. To get the best chance of viewing, have a look online to find a dark sky location near you, or stand in the shadow of a building to reduce light pollution. Wait until after midnight to get the best chance of seeing the space rocks, as we'll be on the night-side of Earth when it hits the meteor stream.

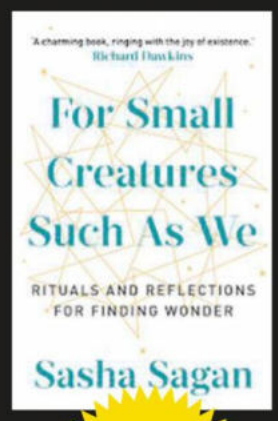
This winter's ***Cambridge Literary Festival*** (29 Nov – 1 Dec) has a wealth of big names, including Richard Dawkins, Gaia Vince and Ian McEwan, but I'm most looking forward to hearing psychiatrist-turned-author Joanna Cannon talk about her time in the NHS and her heartbreaking memoir ***Breaking & Mending***.

If staying in is your thing, animal biologist and presenter Liz Bonnin returns to our screens for BBC One's ***Meat: A Threat To Our Planet?*** Liz travels around the world to discover what price the environment and climate is paying for our attempts to satisfy an insatiable hunger for meat. In the US, she meets the scientists searching for solutions. Then, Liz visits a small farm in Wales and speaks to a family who have decided to rear and kill the animals on their plates themselves. Urging all of us to question our relationship with meat, this is perhaps not one to watch at dinnertime.

> **"Liz travels around the world to discover what price the environment and climate is paying for our insatiable hunger for meat"**

READING LIST

NEW BOOKS TO THUMB THROUGH

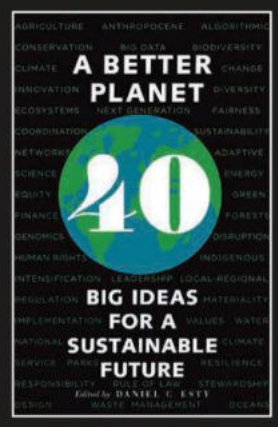


EDITOR'S CHOICE

FOR SMALL CREATURES SUCH AS WE

SASHA SAGAN
£14.99, MURDOCH BOOKS

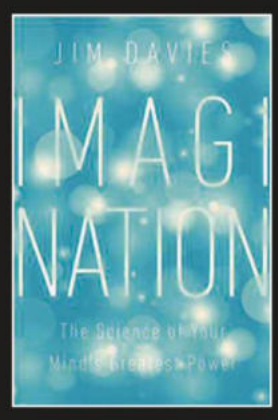
From the daughter of American astrophysicist Carl Sagan comes a new take on modern rituals and spirituality. Showing how science has influenced religious ceremonies for centuries, Sagan reassures atheists that Christmas can be celebrated, honeymoons can be booked and confession is cathartic. Is this *The God Delusion* for the next generation?



A BETTER PLANET: 40 BIG IDEAS FOR A SUSTAINABLE FUTURE

EDITED BY DANIEL C. ESTY
£18.99, YALE UNIVERSITY PRESS

In this time of rapidly changing climate, questions around sustainability need pioneering solutions. This collection of essays offers modern ideas for a globally sustainable way of living, each backed by experts in areas across and beyond science, technology, public health and policy.



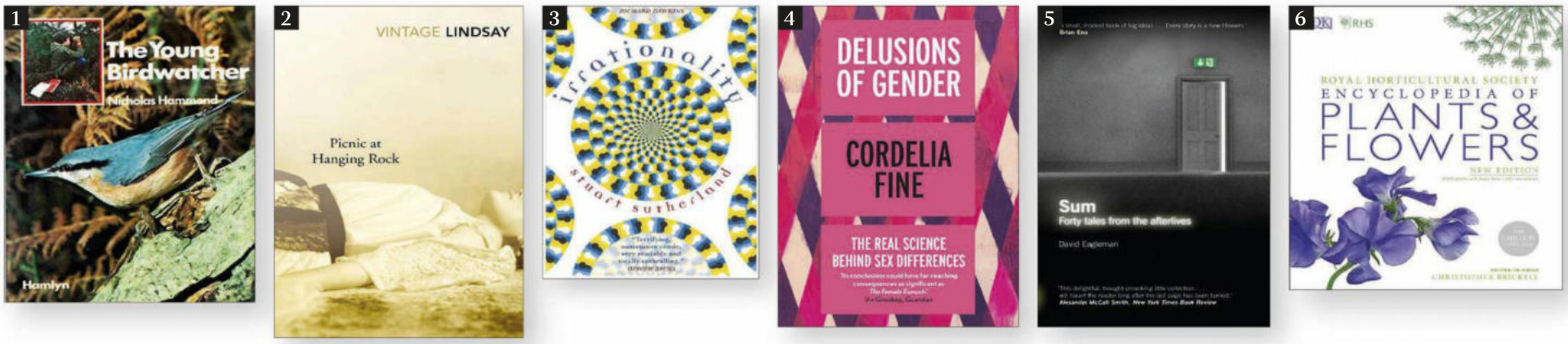
IMAGINATION: THE SCIENCE OF YOUR MIND'S GREATEST POWER

JIM DAVIES
£21.99, PEGASUS BOOKS

How do we conjure up imaginary scenes in our mind? What is going on in our brains when we daydream? Jim Davies, professor at the Institute of Cognitive Science, Carleton University, answers these questions and more in a fascinating look at the inner workings of our creative mind.

THE BOOKS THAT MADE ME: CLAUDIA HAMMOND

CLAUDIA HAMMOND, THE HOST OF BBC RADIO 4'S WEEKLY PSYCHOLOGY PROGRAMME *ALL IN THE MIND*, IS ALSO AN AUTHOR AND TV PRESENTER. HER NEW BOOK, *THE ART OF REST*, REVEALS THE RESULTS OF THE DURHAM UNIVERSITY REST TEST, WHICH FOUND OUT MORE ABOUT HOW WE SPEND OUR DOWNTIME



For the Durham University Rest Test, we asked 18,000 people from around the world what they found the most restful, and reading came out on top. We were quite surprised, because reading is effortful. It beat things like listening to music, being out in nature, having a bath. I think the reason is that a book takes you out of the world you're in. Reading is definitely restful for me. When I was seven, my dad [Nicholas Hammond] wrote ***The Young Birdwatcher*** (1978). It made me realise that even people I knew could write books. My sister and I wanted to be the Brontë sisters. I don't think we realised that things didn't end well for them!

I found a notebook recently where, when I was young, I had graded the novels I read. The only book that got two red stars – which means very, very good – was ***Picnic At Hanging Rock*** (1967) by Joan Lindsay, I read it at 13, and it had a real impact on me. It was about female friendship between these teenage schoolgirls who stood up to their strict teachers together. They go missing after a picnic, and I was completely bewitched by the mystery of not knowing what happened to them. It says at the beginning that it's a true story, and in those days you couldn't look on Wikipedia to find out. I was fascinated to know whether it was real, but I've since found out it's not.

I actually prefer non-fiction to fiction, and my most memorable, most influential books, are non-fiction. When I was at Sussex University studying psychology, I read ***Irrationality*** (1992) by Stuart Sutherland. It's all about cognitive biases in our thinking, and it was way ahead of its time. This book was influential on how useful psychology can be in our everyday lives.

Because there were more male authors than female authors when I was young, so many of my influential books end up being by men. But that will change as time goes on. If I was at university now, I'd be reading books like Cordelia Fine's ***Delusions Of Gender*** (2010). It's all about the science and the many myths of sex differences. It cuts through a load of assumptions that all of us make, all the time, about gender. In a way, this is the book I wish I'd written.

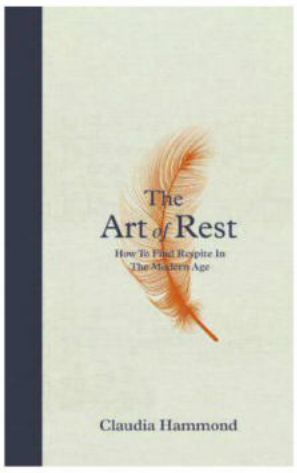
"It made me realise that even people I knew could write books. My sister and I wanted to be the Brontë sisters. I don't think we realised that things didn't end well for them!"

One fiction book that had quite an impact on me was ***Sum*** (2009) by David Eagleman. David is a neuroscientist and has written [nonfiction] books about popular neuroscience. But this is a collection of short stories, where each one is a different version of an afterlife. It's so imaginative.

Gardening is the thing that I find most restful, and so a book I love now is the ***RHS Encyclopedia Of Plants And Flowers*** by Christopher Brickell. I'm constantly looking things up. I'm interested in the Latin names, and what else is it related to, and does it need to be in the sun or not? But it is hugely pleasurable, particularly in winter when there are not many flowers, to flick through it again and think of what's coming.

BBC

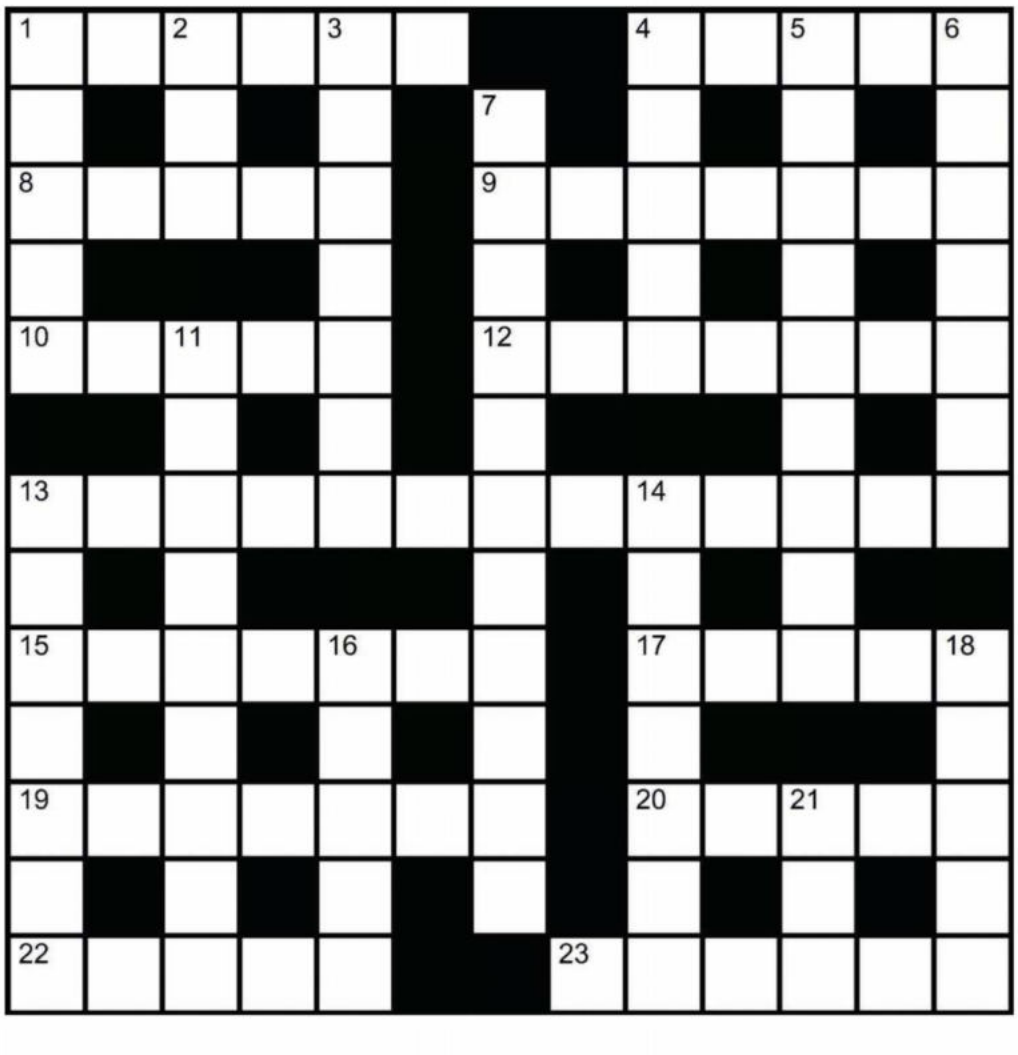
by CLAUDIA HAMMOND
(@claudiahammond)
Claudia is presenter of All In The Mind *on BBC Radio 4, and* Health Check *on BBC World Service.*



THE ART OF REST
CLAUDIA HAMMOND
(£16.99, CANONGATE)
OUT 5 DECEMBER

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Oedema falls on your head (6)
4 Relish impudence (5)
8 Growth in college parking (5)
9 Oral broadcast around America causes excitement (7)
10 Sense volunteers set off (5)
12 Island nation has five, right behind urn (7)
13 A baleful point about egg transport system (9,4)
15 One old message – start voice about organic fuel (7)
17 Pen the French fashion (5)
19 It provides fruit – alternatively a vegetable (7)
20 Old lie about banishment (5)
22 A bunch of detectives contain resistance that's strong (5)
23 Time city accepted key organisation (6)

DOWN

1 Son left tycoon in warehouse (5)
2 Fuel orders start – one left (3)
3 Dine more extravagantly as leader (7)
4 Most upset about rubella's first outbreak (5)
5 A French canape might be disreputable (9)
6 Expand directions on Elgar composition (7)
7 Sarcastic like this, attorney gets some soap (7,4)
11 Room around river for a vehicle (6,3)
13 Aim for treatment to include initially benign tumour (7)
14 Money put aside by Robin, say (4,3)
16 Trophy is a drawback (5)
18 European, cheerful with no right to be abrasive (5)
21 Something charged out of stationer's (3)

SHUTTERSTOCK

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

BAH HUMBUG! WHY POSITIVITY IS OVERRATED

PLUS

SPEAKING TO PEOPLE IN COMAS

Research suggests that people in vegetative states are more responsive than we might have thought.

HANNAH FRY

We chat to the mathematician and BBC presenter about her role as this year's host of the Christmas Lectures.

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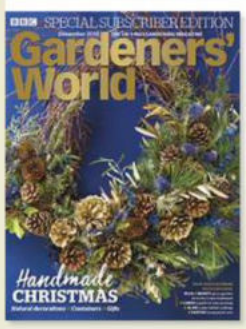

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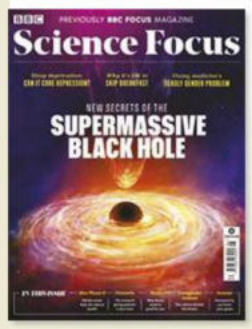

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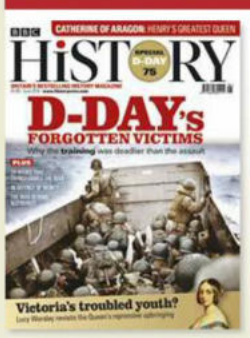

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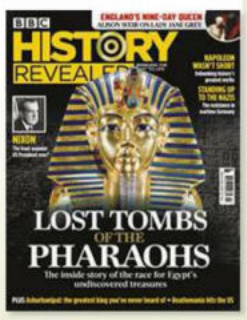

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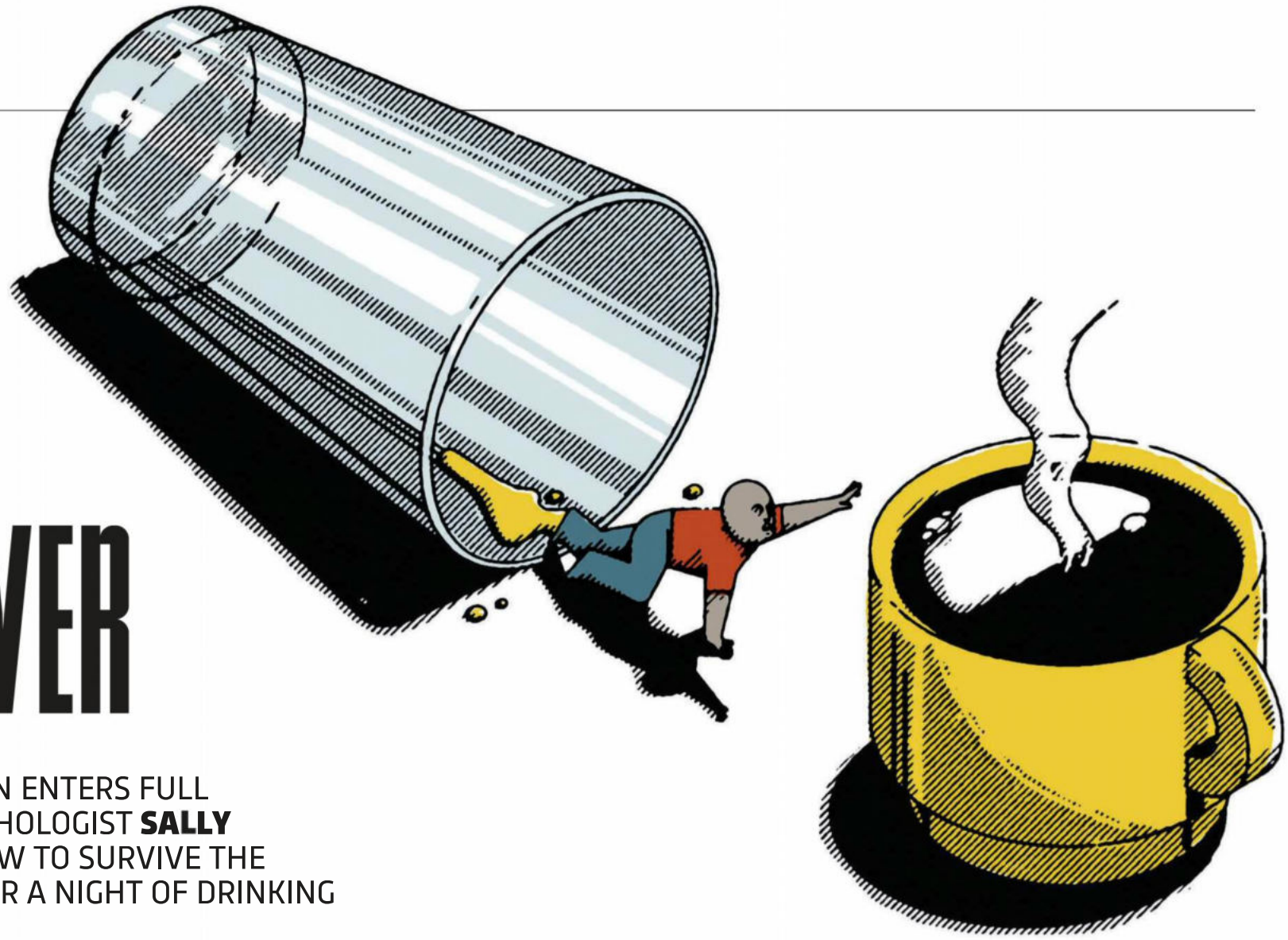


A SCIENTIST'S GUIDE TO LIFE

THE HANGOVER

AS THE PARTY SEASON ENTERS FULL SWING, HEALTH PSYCHOLOGIST **SALLY ADAMS** EXPLAINS HOW TO SURVIVE THE REPERCUSSIONS AFTER A NIGHT OF DRINKING

WHAT CAUSES A HANGOVER?

It's more than just dehydration. Alcohol irritates the stomach and small intestine, which can lead to stomach upsets. It causes an imbalance in electrolytes, and when we break down alcohol, we produce a toxic chemical called acetylaldehyde. This can be responsible for the racing heart, the sweating and the nausea.

DO SOME DRINKS GIVE YOU LESS OF A HANGOVER THAN OTHERS?

We're not sure. One study found that dark coloured drinks like red wine and bourbon seem to give worse hangovers than light coloured drinks like gin and vodka, but the effect was subjective. Although people said they felt different, they didn't act any different. I think it's more about the volume you consume rather than the type of drink.

WHY DO SOME PEOPLE GET WORSE HANGOVERS THAN OTHERS?

The severity depends on lots of things, including your weight and what you've eaten that day. Genetics also plays an important role.

DO HANGOVERS GET WORSE WITH AGE?

Possibly. There's some evidence to suggest that as we age, the body becomes less effective at metabolising alcohol, perhaps because our liver mass decreases. Also, the way we drink is different. As we age, heavy drinking episodes tend to be less frequent so you become less tolerant to the effects of alcohol.

WHAT'S THE BEST WAY TO AVOID A HANGOVER?

Drink in moderation. That's the only way. Eating a fatty meal before you go out drinking might also help because it can slow down the absorption of alcohol into the bloodstream.

WHAT'S THE BEST WAY TO BANISH A HANGOVER?

There is no cure, but you can treat some of the symptoms. Water can aid with the dehydration, painkillers can help to calm an irritated stomach, and sports drinks can help restore the balance of electrolytes. Alcohol consumption also affects sleep quality, so getting some extra shuteye is a good idea.

HAIR OF THE DOG, A FRY-UP, OR A WORKOUT?

Hair of the dog prolongs the inevitable. It's not a good idea to treat a hangover with more booze. Fry ups might aid with metabolising alcohol. Eggs and bacon contain an amino acid called cysteine, which helps to break down the acetylaldehyde that is produced. There's no evidence that exercise can help a hangover. What might happen is that you become more dehydrated, which could make you feel even worse.

ONE MESSAGE FOR OUR READERS?

Even when the alcohol's out of your system, you're still impaired. We make poorer decisions when we're drunk, but research shows that we continue to make bad decisions when we are hungover. People with hangovers struggle with attention, memory and motor skills, so even if you think you're fine to drive a car, go to work, or look after the kids, you might not be. Drink in moderation and be careful the next day. SF

DR SALLY ADAMS
(@sallyscientist)
Sally is a health psychologist at the University of Bath. She researches the cognitive effects of alcohol and tobacco. ***Interviewed by Dr Helen Pilcher.***

NEED TO KNOW...

1

Some of us may be destined to get bad hangovers, thanks to genetics.

2

It might be boring, but the only way to avoid a hangover is to drink in moderation.

3

Stay away from the hair of the dog – it only prolongs the inevitable.

ILLUSTRATION: MICHAEL HADDAD

the science of good bone structure

You may think bone is solid or fixed.
In fact it is living tissue, in constant change.
To keep bones healthy you must have the right nutrients in your daily diet.

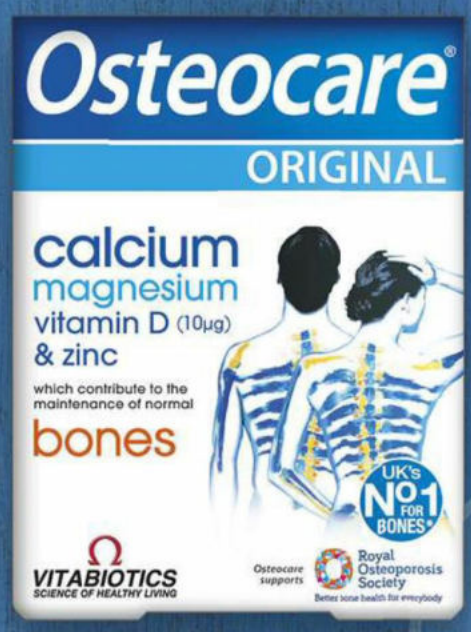
Calcium is essential to help maintain normal bones, as is vitamin D, which is necessary for the normal absorption and utilisation of calcium. But did you realise magnesium and zinc are important for bones too? Both men and women need to look after their bones throughout their life, and remember it's never too early or too late to start a bone-friendly way of life!

FIZZ

Makes a tasty drink.
A convenient, refreshing orange flavoured effervescent drink.

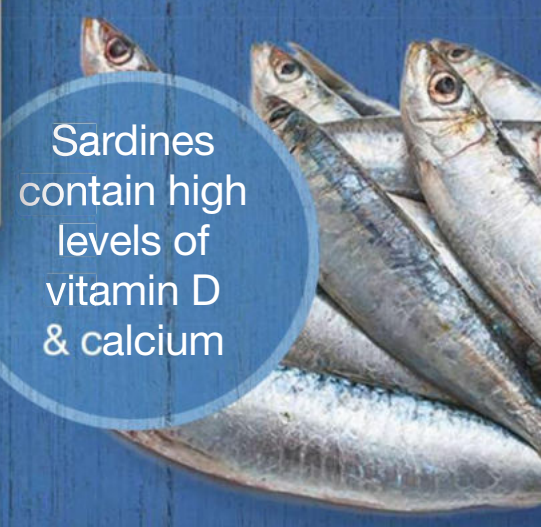
Healthy tip:

Leafy greens contain minerals such as magnesium and calcium



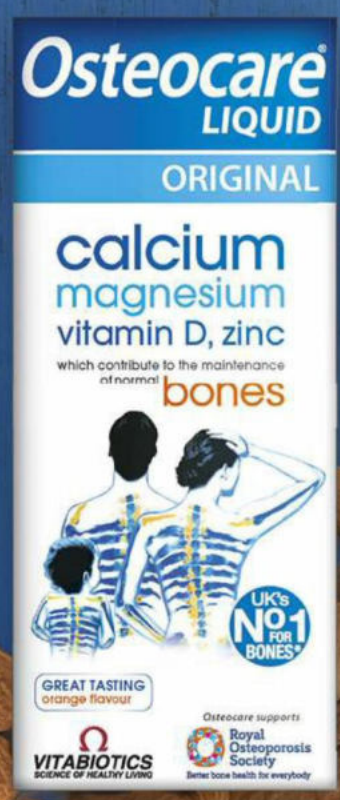
ORIGINAL

More than just calcium.
Provides calcium carefully balanced with vitamin D, zinc and magnesium which all contribute to the maintenance of normal bones.



Healthy tip:

Sardines contain high levels of vitamin D & calcium

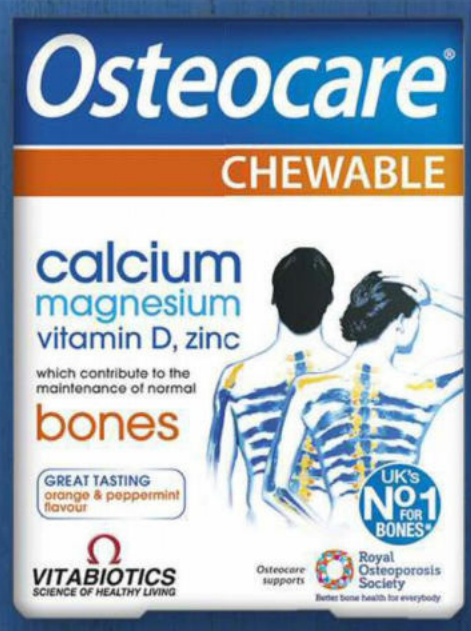


LIQUID

Excellent taste.
Ideal for children or those who have difficulty swallowing tablets.
Available in 200ml and 500ml.

Healthy tip:

Almonds are a great source of magnesium and zinc



CHEWABLE

Easy to take.
Provides the original formula in a great tasting peppermint and orange flavoured chewable tablet.

*UK's No.1 bone health supplement brand. Source: Nielsen GB ScanTrack Total Coverage Unit Retail Sales 52 w/e 18 May 2019. To verify contact Vitabiotics Ltd, 1 Apsley Way, London NW2 7HF.

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Better bone health for everybody

UK's No.1 FOR BONES*

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POSITION YOURSELF ON TOP OF THE GAMER COMMUNITY FOOD CHAIN!

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by iiyama

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Both will be 34 inches with Ultra-Wide QHD resolution, have IPS panels with FreeSync™, 1ms MPRT response time with 144Hz refresh rate, AND the GB3466WQSU will be curved!

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